MDNR PRELIMINARY
DRAFT PROCESS DOCUMENT

June 2003

This draft document is a summary of the policy choices made during various stakeholder meetings and by the eight stakeholder subgroups. These policy choices in part form the basis of Missouri's risk based decision making process to manage contaminated sites. Specific implementation details will be included in the overarching and program specific guidance documents.

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/RBDM	
ASTM	American Society for Testing and Materials
AUL	Activity and Use Limitation
bgs	Below Ground Surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Chemical of Concern
DAFs	Dilution Attenuation Factors
DTL	Default Target Level
EM	Exposure Model
EPA	Environmental Protection Agency
ft	Feet
GW	Ground Water
HI	Hazard Index
HQ	Hazard Quotient
IELCR	Individual Excess Lifetime Cancer Risk
IRIS	Integrated Risk Information System
ISC	Initial Site Characterization
MCL	Maximum Contaminant Level
MDNR	Missouri Department of Natural Resources
MRBDM-RA	Missouri Risk Based Decision Making for Remedial Action
NAPL	Non-aqueous Phase Liquid
NCEA	USEPA National Center for Environmental Assessment Summary Tables
NFA	No Further Action
ORNL	Oak Ridge National Laboratory
POD	Point of Demonstration
POE	Point of Exposure
RBSLs	Risk-Based Screening Levels
RCRA	Resource Conservation and Recovery Act
RMP	Risk Management Plan
SCM	Site Conceptual Model
SSTLs	Site-Specific Target Levels
UST	Underground Storage Tank
VCP	Voluntary Cleanup Program

1.0
EXECUTIVE SUMMARY

This **process document** summarizes the draft decisions made by the stakeholder group working on "**Missouri Clean Water Commission's Risk Based Groundwater Remediation Rule**". This stakeholders group was convened at the request of the Missouri Clean Water Commission.

The large group of stakeholders met several times since June 2002. The initial meetings focused on:

- Developing a common understanding of the risk based decision making process,
- Specific policy choices/decisions that had to be made to develop a Missouri specific risk based decision making system,
- Overall characteristics and objectives of the process, and
- Desired outcomes of the process.

Minutes for each of the large group meeting were prepared and are included as appendicies to this document.

Subsequent large group meetings focused on a discussion of and decisions related to the policy choices. To better focus the large group efforts, and to encourage in-depth discussion of selected policy choices, eight subgroups were formed and each group was assigned a specific policy issue to discuss and make recommendations. Each of these subgroups prepared a draft report outlining the consensus decisions and any dissenting opinions. These eight subgroup reports are included as appendicies to this document.

This draft process document summarizes the key decisions (i) made by the large group, and (ii) decisions made by the eight subgroups. In a few cases the subgroup reports were not entirely clear, hence this document includes some interpretation of the subgroup reports. The reader is encouraged to review the subgroup reports.

It is anticipated that this draft process document will be modified based on a review (i) by the large group, and (ii) of lessons learnt during the completion of the pilot projects. The final process document will form the basis of Risk Based Decision Making Process to manage chemically impacted sites in Missouri. Implementation details will be included in the overarching Guidance Document. ***The final process document is scheduled to be completed by end of 2003.***

2.1 INTRODUCTION

The ***Missouri Department of Natural Resources (MDNR)*** is faced with the challenging task of overseeing the most appropriate response actions at contaminated sites across the state. These sites are managed under a variety of different regulatory programs. Whereas the primary objective of each program is to protect human health, environment, and natural resources, the specific decision-making framework has varied from program to program. Thus within MDNR there are several decision making frameworks used to address contaminated sites. Because the science and state of practice has advanced in recent years, and not all regulatory programs had fully incorporated a risk-based approach to remediation, the Department undertook an effort with a Stakeholders' Committee to review and revise its approach to cleanup of contaminated sites.

It is anticipated that this revised approach will result in a more consistent and predictable regulatory process for property owners and developers, and possibly a reduction in the overall cost of cleanups. Although the MDNR will not allow cost considerations to compromise public health or the environment, it recognizes the need to promote cost-effective site activities (characterization as well as remediation) that are protective of human health, environment, and natural resources.

This integrated risk based decision-making framework, termed ***Missouri Risk Based Decision Making for Remedial Action (MRBDM-RA)***, is **subsequently referred to as RBDM.** This customized framework builds on the generic framework developed by American Society for Testing and Materials (ASTM) in their standard E1739-95.

Though various MDNR programs impose several program-specific administrative and notification requirements on the responsible party and the regulators, it is intended that the identification of the nature and extent of risk management actions required to restore sites to levels protective of human health, environment, and natural resources will be based on this framework. Thus this process framework will result in an agency-wide consistent decision-making framework yet accommodate the unique administrative requirements of the various regulatory programs.

When implemented, the RBDM approach will be applicable to all media and all contaminated sites. Nor the responsible party or the regulators will have the choice to pick or choose the media or sites to which this process will apply. Further, risk management decisions made through the application of this process will be acceptable to all regulatory programs dealing with the management of contaminated sites.

This document does not in any way replace or supercede MDNR's enforcement or permitting authority, notification requirements, or other applicable requirements, nor does it reduce any of the responsible party's obligations under state law or regulations. Once a site has been identified as requiring corrective action, this document provides a framework to determine site-specific cleanup levels and the associated risk management activities required to restore sites such that the residual concentrations of chemicals of concern at the site are protective of human health, environment, and natural resources.

2.2 STEPS IN THE RBDM PROCESS

The overall decision-making process for a site where contamination is discovered or suspected is illustrated in the flowchart in Figure 2-1. The process consists of **seven** steps, each of which is briefly discussed in the following sections:

2.2.1 Step 1: Site Discovery

The risk based site management process begins with the discovery of a contaminated or potentially contaminated site. A contaminated site may be discovered and reported to the MDNR under a variety of circumstances. These include, but are not limited to, citizen complaints, investigations conducted as a part of real estate transactions, investigations conducted in anticipation of land development, environmental impacts observed in surface water bodies, and notification of accidents and spills. Various statutes and regulations administered by MDNR (UST, VCP, RCRA, CERCLA, etc.) impose specific notification requirements on the responsible parties. This document does not change any of these responsibilities. It is the responsible party's obligation to perform the initial notification as per the requirements of specific MDNR programs.

2.2.2 Step 2A: Determination of Imminent Threat

Upon site discovery, the initial step is to carefully evaluate the available information to determine whether the site poses any imminent threat to human health, safety, or environment. These include but are not limited to impacts to water-use wells, vapors or odors in residential and commercial structures, concentrations approaching explosive levels, visual impacts to a surface water body, and impacts to wild-life, vegetation, or endangered species, (e.g. fish kills). If any imminent threats are identified, the MDNR should be informed immediately and steps taken to abate the threat.

2.2.3 Step 2B: Initial Abatement/Emergency Response Actions

If an imminent threat is identified, the responsible party shall immediately initiate abatement actions. Examples of abatement measures include provision of alternate water supply if drinking water wells are impacted, evacuation of residents/commercial workers if exposed to vapors at high concentrations, installation of booms on surface water bodies with a sheen, or ventilation of utilities with vapors. Upon completion of these measures, a report documenting the activities and confirming that the imminent threats have been abated shall be submitted to the MDNR. This report shall also include recommendations related to any additional follow on work that may be necessary to confirm protection of human health and the environment over the long term.

2.2.4 Step3A: Initial Site Characterization

Upon completion of the emergency response action, or upon site discovery if no emergency action is necessary, an ***Initial Site Characterization (ISC)*** is performed. This will include collection of media-specific data (e.g. soil, surface water, and groundwater) to characterize the residual source of ***chemicals of concern (COC)***. Depending on site conditions, this step will involve limited but focused field work that may involve drilling temporary wells, collection of soil samples, etc. aimed at identifying the maximum concentrations of chemicals of concern in the affected media (soil, groundwater etc.). At this stage, an initial screening level evaluation shall be completed to identify any ecological issues at the site that may warrant detailed evaluation.

2.2.5 Step 3B: Comparison with Default Target Levels

This step involves the comparison of maximum site concentrations with the ***default target levels (DTLs)***. If the maximum media-specific concentrations at a site are less than the DTLs, and no ecological issues exist, the MDNR will grant the site a "no further action" status. If the maximum soil or groundwater concentrations exceed the DTLs, but no ecological issues exist at the site, the responsible party may (i) adopt DTLs as the cleanup levels and develop a risk management plan to achieve these levels, or (ii) perform a Tier-1 evaluation. Since a site may be granted ***No Further Action (NFA)*** based on comparison with DTLs, it is very important that the data collected in the ISC, identify the maximum media-specific concentrations. A NFA determination at this step means that the residual concentration of present at the site do not pose an unreasonable risk, regardless of how the site may be used or developed in the future.

The term maximum concentration refers to the current maximum concentration and not the historic maximum concentration. This would be particularly significant at sites where the current concentrations may be different due to remedial activities, natural attenuation processes, or additional releases.

2.2.6 Step 4: Development and Validation of Site Conceptual Model

If steps described in 2.2.4 and 2.2.5, do not result in a NFA or the DTLs are not selected as the cleanup levels, it is necessary to develop and validate a ***site conceptual model (SCM)***. A SCM provides the framework for the overall management of the site and should help guide the data collection and subsequently the risk management activities at the site. Key elements of the SCM include (i) release scenario, contaminant source, and chemicals of concern, (ii) ***exposure model (EM)*** that focuses on the receptors, pathways and routes of exposure and identifies the complete routes of exposure under current and reasonable future land use conditions; (iii) site stratigraphy and hydrogeology, and (iv) spatial and temporal distribution of chemicals of concern. An important part of this step is the validation of the SCM based on the collection of site-specific data. This is similar to the traditional site investigation step in that it may involve, but not be limited to, the installation and sampling of monitoring wells, and collection of soil data both on-site and off-site. Additionally, it involves the determination of land use to develop the EM.

2.2.7 Step 5A: Tier 1 Evaluation

Tier 1 evaluation requires the (i) selection of relevant Tier 1 ***Risk Based Target Levels (RBSLs)*** from lookup tables developed by the MDNR, (ii) adjustment of these levels to account for additivity of risk, and (ii) comparison of these levels with representative concentrations. Tier 1 levels will be selected for each COC, each complete pathway, and each media identified in the exposure model.

2.2.8 Step 5B: Comparison with Tier 1 RBSLs

The modified Tier 1 levels calculated in Step 5A are compared to representative concentrations of the chemicals of concern. Based on this comparison, one of the following three decisions is made:

- NFA if the representative concentrations do not exceed the modified RBSLs and other conditions for NFA have been met e.g. absence of any nuisance conditions,

- Adoption of modified RBSLs as the cleanup levels and the subsequent development and implementation of a ***risk management plan (RMP)*** to achieve these levels,

- A Tier 2 evaluation.

Upon completion of the Tier 1 evaluation, the responsible party shall provide their recommendations to the MDNR.

2.2.9 Step 6A: Identification and Collection of Data for Tier 2 Evaluation

Depending on the site-specific conditions, Tier 2 evaluation may require the collection of additional site-specific data. In preparation for a Tier 2 evaluation, the EM should be revised if necessary and as appropriate additional data collected. This data would be used to develop Tier 2 site-specific target levels using MDNR's guidance. Since tier 2 evaluation could vary significantly based on site-specific considerations, a work plan which outlines the overall approach for tier 2 evaluation may be necessary and require MDNR's approval. However, if the only change is to replace default fate and transport factors with site-specific fate and transport parameters, a work plan may not be necessary.

2.2.10 Step 6B: Development of tier 2 Site-Specific Target Levels

This step requires the development of tier 2 ***Site-Specific Target Levels (SSTLs)*** for all complete pathways, media, and COCs identified in the previous steps. The person performing the evaluation is expected to follow the approved work plan.

2.2.11 Step 6C: Comparison with tier 2 SSTLs

After the tier 2 SSTLs have been developed they shall be compared with representative concentrations. Depending on the comparison, the following two outcomes are possible:

- NFA determined by MDNR if the representative concentrations do not exceed the tier 2 SSTLs and other conditions for NFA have been met e.g., absence of nuisance conditions,

- the MDNR is satisfied that the site had been adequately characterized, or

- Adoption of tier 2 SSTLs as cleanup levels and the development and implementation of a RMP.

2.2.12 Step 7A: Development and Implementation of Risk Management Plan

This step involves the development and implementation of RMP to achieve the cleanup levels approved by MDNR. Typically a RMP will be developed after the approval of media-specific cleanup levels and may include a combination of active and passive remedial options and/or activity and use limitations. As appropriate, the plan should include (i) the type of technology to be used, (ii) any activity use limitations, (iii) the time it may take to implement the RMP, (iv) data that will be collected to monitor the effectiveness of the RMP, (v) the manner in which the data will be evaluated, and (vi) steps that will be taken if the RMP is not as effective as anticipated. It is important that during the implementation of the RMP, sufficient data be collected and analyzed to evaluate the performance of the plan and make modifications as appropriate. The RMP shall not be implemented until approved by the MDNR.

2.2.13 Step 7B: Modification of the Risk Management Plan

The data collected during implementation of the RMP shall be carefully evaluated and a determination made whether the RMP is progressing as anticipated. If significant deviations are identified, modifications to the RMP shall be determined and communicated to MDNR. In particular, the RMP shall be revised if the data indicates that site cleanup is not progressing at the rate anticipated. The specific modification will vary from site to site.

2.2.14 No Further Action Under the RBDM Program

The overall objective of all RMPs is to ensure the long-term protection of public health, environment, and natural resources under current and reasonable future conditions. When the MDNR is satisfied that the concentrations of the chemicals of concern have met the cleanup levels, and that these levels will be maintained in future, the MDNR will grant a NFA status to the site. This implies that based on the information available to the MDNR at the time, no further action is necessary to protect human health, natural resources, and the environment. However, if in the future additional information becomes available that indicates the likelihood of unacceptable risk, the MDNR may rescind their decision and re-open the site.

2.3 RATIONALE AND CHARACTERISTICS OF TIERED APPROACH

A site will receive NFA status if the COC concentrations are below the selected cleanup levels and either no ecological or other issues exist at the site or they have been adequately addressed. A brief discussion of these target levels is presented below:

Default Target Levels (DTLs) are the most conservative chemical and medium specific concentrations that allow unrestricted (residential) use of the property. For each chemical, the DTL is the lowest of the Tier 1 RBSLs. Since DTLs are the most conservative levels, their application does not require the evaluation of site-specific exposure pathways, the development of a site conceptual model, any activity use limitations, or the determination whether groundwater is potable or not.

Tier 1 RBSLs are generic levels developed by MDNR using conservative default parameters that depend on the receptor, media, pathway, route of exposure, and the determination of whether impacted or threatened groundwater is potable and likely to be used for domestic use. Use of RBSLs may require activity use limitations. Prior to their application, the tabulated RBSLs have to be modified to account for additivity of risk.

Tier 2 SSTLs are site-specific levels that are based on the data collected at the site and the guidelines included in this document. Compared with tier 1 RBSLs, tier 2 SSTLs may be based on modification of just a few site-specific parameters or a more detailed site-specific evaluation involving different fate and transport models.

Table 2-1 presents the differences between the different target levels within this framework.

2.4 ANTICIPATED IMPACTS ON SITE COSTS

As a site moves through this tiered process following may be anticipated:

- Higher tiers will require the collection of additional site-specific data, which will increase the cost of data collection and analysis, and labor cost. Simultaneously, there will be a reduction in the overall uncertainty about the site,

- In general, the calculated tier 2 SSTLs will be higher than the tier 1 modified RBSLs because lower tier levels are designed to be more conservative than higher tier levels. Thus, the cost of risk management activities shall be lower at higher tiers,

- The need for and the extent of regulatory oversight and review will increase, and

- The level of uncertainty and conservatism will decrease due to the availability of more site-specific data

Despite the above differences, there is one very significant similarity. Each level will result in an acceptable level of protection of human health, environment, and natural resources.

TABLE 2-1 COMPARISON OF THREE TIERS

FACTORS	DTL	Tier 1	Tier 2
Exposure Factors	Default	Default	Site-Specific/ default
Toxicity Factors	Default	Default	Default or MDNR accepted values
Physical and Chemical Properties	Default	Default	Default or MDNR accepted values
Fate and Transport Parameters	Default	Default	Site-Specific
Unsaturated Zone Attenuation	Depth to water table dependent	Depth to water table dependent	Depth to water table dependent/ Site Specific
F&T Models	Default	Default	Acceptable to MDNR
Representative Concentrations	Maximum	Calculated	Calculated
IELCR*	NA	Cumulative effects considered if more than 10 carcinogenic COCs	Cumulative effects considered if more than 10 carcinogenic COCs
Hazard Quotient	NA	Cumulative effects considered if more than 10 non-carcinogenic COCs	Cumulative effects considered if more than 10 carcinogenic COCs
GW Protection	MCL or equivalent	Site Specific Evaluation	Site Specific Evaluation
Ecological Risk	NA	Evaluate	Detailed Evaluation
Outcome of Evaluation	NFA, Tier 1	NFA, Tier 2, RMP	NFA, RMP
SW Protection Mixing Zone	?	?	?
GW Point of exposure	N/A	?	?
Institutional Controls	N/A	Considered	Considered

* See text for details

RMP: Risk Management Plan

IELCR: Individual Excess Lifetime Cancer Risk

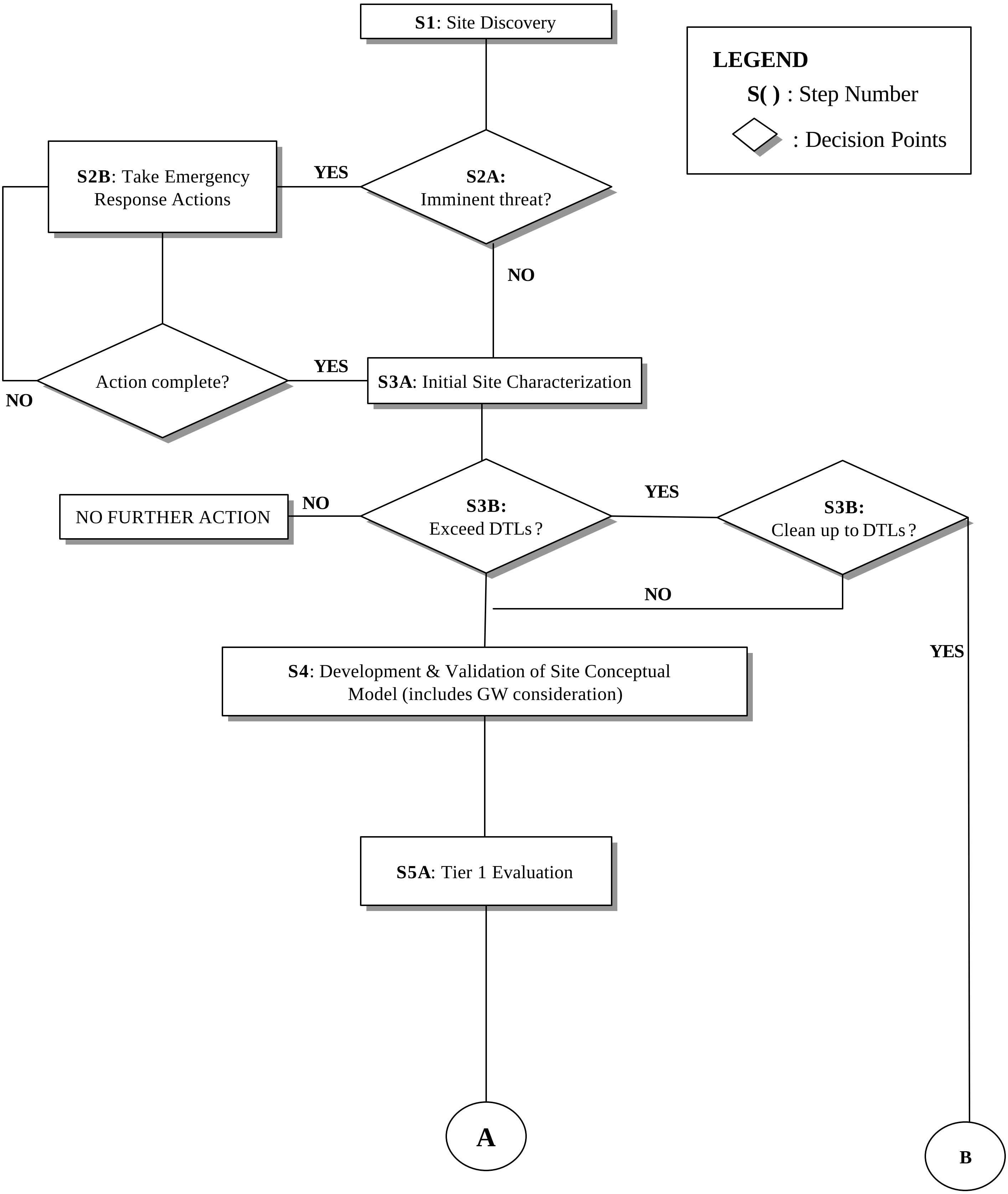


Figure 2-1 RBDM Process Flowchart (*page 1 of 2*)

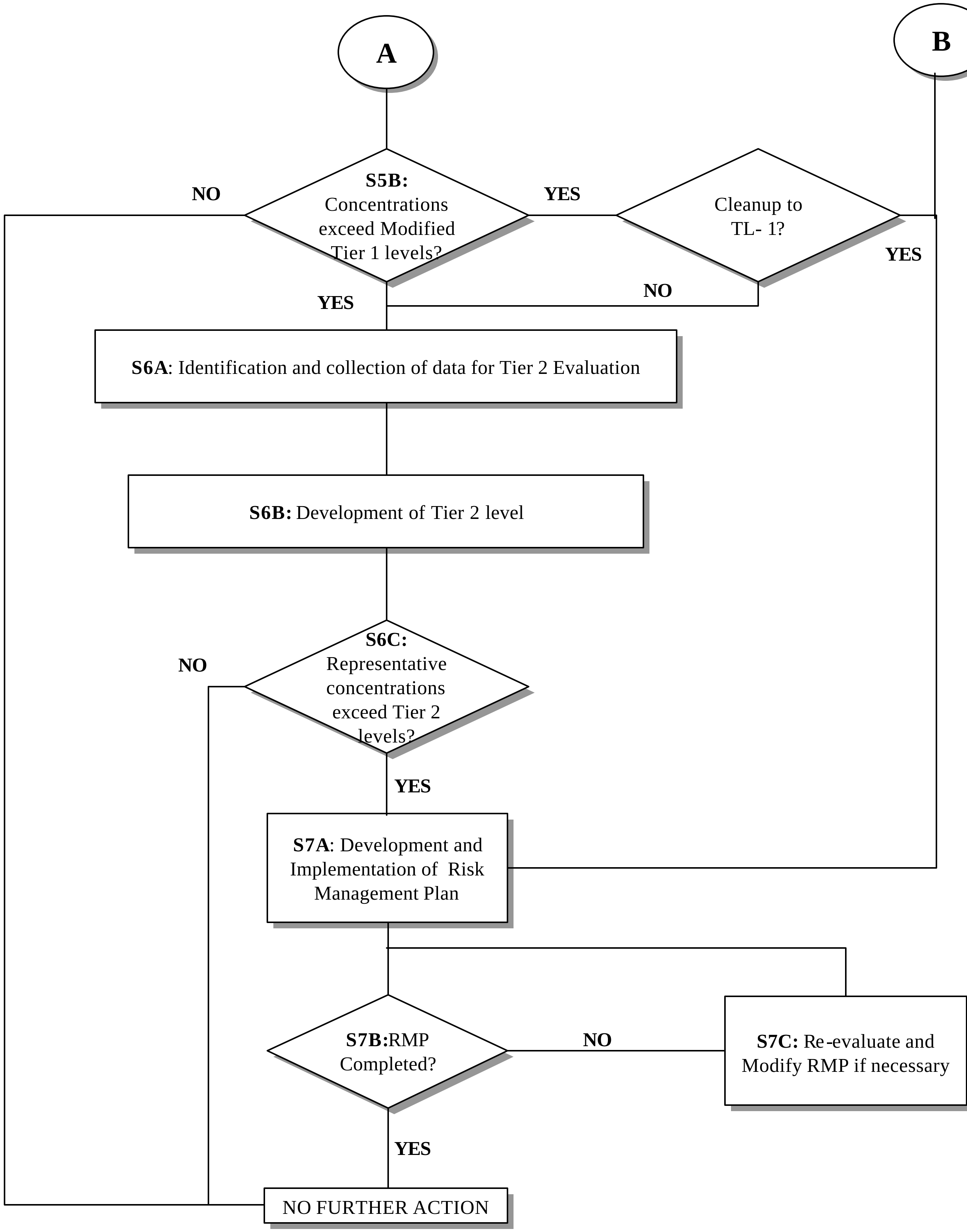


Figure 2-1 RBDM Process Flowchart (*page 2 of 2*)

3.0
RISK-BASED EVALUATION: GENERAL CONSIDERATIONS

Missouri's Risk Based Decision Making Process requires the consideration of several factors common to the performance of tiered risk evaluation. These factors are discussed in this section.

3.1 LAND USE

The characterization of the human receptors and the activities on and adjacent to the release site is a critical component of this process because human exposure and hence risks are dependent on land use. To determine relevant cleanup levels for a site, it is important to determine the current and reasonably likely future use(s) of the property.

The current and recent uses of the property and surrounding area must be clearly identified on maps and included in the site characterization report to MDNR. As a general rule, the maps should extend 500-1000 feet beyond the area likely impacted by the chemicals of concern. Reasonable judgments should be made concerning the distance beyond the boundaries of the contaminated site to which the responsible party should identify land uses.

Current and reasonably likely future land use must be categorized as either "residential" or "non-residential." The "residential" category results in lower cleanup target levels. If a risk management plan is based on (current or likely future) "non-residential," conditions an appropriate ***Activity and Use Limitation (AUL)*** may be required. AULs may include appropriate institutional controls and/or engineering controls.

While it is not possible to identify every scenario in this document, the following guidelines are intended to assist in making the land use determination:

- **Residential or unrestricted land use–** Includes land uses where persons can be expected to reside for more than 8 hours a day, 7 days a week, over an extended period of time. Examples include homes, apartments, hospitals, nursing homes, schools, childcare centers, farms with houses.

- **Non-Residential –** Includes land uses where persons can be expected to be on site less than 10 hours a day, and absent on weekends and holidays. Examples include retail facilities, industrial and manufacturing operations, fleet operations, hotels and motels.

(Note: When a planned development for an impacted site includes a multi-story building, or mixed use, the presence of a day care facility or apartments on an upper floor does not necessarily mean the land use is "residential." Reasonable assumptions concerning exposures on the ground floor of the building should be used to develop cleanup levels.)

3.1.1 Determine Current Land Use

Current land uses and activities must be identified and evaluated to be protective of the existing receptors. Current land use refers to land use as it exists today and can be readily determined by a site visit. Thus there should be no ambiguity about current land use.

A site reconnaissance should identify homes; playgrounds, parks, businesses, industries, or other land uses at the site of the release and in close proximity (upto 500 -1000 feet beyond the area of impact). As appropriate, zoning maps, state or local zoning boards, the U.S. Bureau of the Census, topographic, land use, housing and other types of maps, and aerial photographs can provide information for determining land use.

Undeveloped land adjacent to or in close proximity of the site should be characterized by the most likely future use of that property. If the undeveloped parcel is located in an area, which is predominantly non-residential, then the non-residential classification may be appropriate. However, if the setting is more rural or the land-use is mixed, the undeveloped land should be considered residential unless the responsible party imposes an AUL or one already exists that is acceptable to MDNR.

3.1.2 Determine Most Likely Future Land Use

Knowledge about the most likely future use of the site and adjacent properties is necessary to identify future exposure points, exposure pathways, and exposure factors. Consideration of these pathways ensures that the site-specific decisions are protective of reasonably possible future site conditions. The exposures to be evaluated in a human health or environmental risk assessment depend upon the activities that could occur under future uses of the land.

Future land use is uncertain and may be influenced by existing or proposed AULs. Most likely future uses and activities must be identified based on local zoning ordinances, knowledge of current and changing land use patterns, zoning decisions, community master plans, interviews with current property owners, non-residential appraisal reports, proximity to wetlands, critical habitat, and other environmentally sensitive areas.

3.2 ONSITE AND OFFSITE

Risk based evaluations must consider the impact of the chemicals to the onsite and offsite receptors. Chemicals released at a site may impact multiple land-uses and multiple receptors. For example, a plume may have migrated offsite below a residential and a non-residential area. In such situations both offsite residential and non-residential receptors have to be considered while developing the EM. For simplification, the following definitions shall be used:

- ***Onsite**: The property located within the current legal property boundaries within which the source of the release is located. This includes soil, groundwater, surface water, and air within those boundaries.*
- ***Offsite**: The property(s) of concern located outside the boundaries of the property where the source of the release is located. This includes the soil, groundwater, surface water, and air located offsite.*

Site characterization will include a determination of the onsite and offsite areas of impact.

3.3 RECEPTORS

Under this process, risk to both human and ecological receptors has to be considered. The human receptors shall include all persons who may be exposed to site-specific chemicals both on-site and off-site. For residential land use, target levels shall be developed for an adult, age-adjusted individual, and a child. The lowest of these three target levels would be applicable to the residential scenario. For non-residential land use, target levels be developed for an adult. Additionally a construction worker shall be considered.

Thus the human receptors include:

Residential – Child, adult, and age-adjusted individual
Non-residential Worker - Adult   Construction Worker – Adult

It is anticipated that the above receptors will be the most exposed human receptors. Other human receptors such as visitors or maintenance workers will generally have less exposure and therefore their exposure and risk may not be quantified.

There are certain sites such as conservation areas, sensitive resource areas, where ecological receptors may be significant. In these areas exposure to wetlands, sensitive environments, wildlife and/or threatened and/or endangered species should be evaluated and as appropriate an ecological risk evaluation completed. The level of cleanup at such sites should be based on the lower of the target levels for human and ecological receptors. Ecological risk evaluation process is further discussed in Section 3.12.

As appropriate, surface water bodies should be evaluated to determine the impacts of discharging groundwater or surface runoff from the release site. At a minimum, information on the location, flow rates, depth, flow direction, and designated beneficial uses of surface water bodies should be evaluated. Also refer to Section 3.9 for additional details.

Onsite as well as offsite underground utilities and specifically, their ability to serve as conduits should be fully evaluated. Adverse impacts to the utilities may include degradation of water and sewer lines; vapors in storm and sanitary sewers; property damage to outer coatings of gas lines; damage to plastic lines, and property damages to buried phone and electrical lines due to contact with chemicals. Such impacts will be evaluated on a case by case basis.

3.4 HUMAN EXPOSURE PATHWAYS

A receptor comes in contact with COCs only if there exists a complete exposure pathway under current (Section 3.1.1) or future (Section 3.1.2) land use conditions. For a pathway to be complete, there must be a (i) source of chemical, (ii) mechanism by which the chemical is released, (iii) medium through which a chemical travels from the point of release to the receptor location, and (iv) route of exposure by which the chemical enters the receptors body and causes potential adverse health effects. Items (i), (ii), and (iii) are critical in determining the exposure domain of the receptor(s).

The exposure domain for a pathway is the area over which the receptor may be exposed to the contaminated medium by the route of exposure. Determination of the exposure domain is critical in developing appropriate representative concentrations for each exposure and pathway. An impacted site may have multiple exposure domains, one for each receptor and each complete route of exposure.

Commonly encountered exposure pathways for which an evaluation must be conducted to determine whether a complete exposure pathway exists at the release site. These pathways are discussed below. At sites where receptors or routes of exposure other than those discussed below are important, the responsible party shall identify them and discuss their quantitative evaluation with MDNR. All complete exposure pathways must be evaluated as part of the exposure assessment.

3.4.1 Pathways for Inhalation

For the inhalation pathway, the chemical intake occurs by the inhalation of vapors at a site both indoors and outdoors. Depending on the toxicity of the chemical, unacceptable exposures may occur at concentrations below the odor threshold levels. In most cases, the source for these vapors is volatile chemicals in soil and/or groundwater that volatilize and diffuse through the overlying capillary fringe, unsaturated zone, and cracks in the floor/foundation to indoor or outdoor air where the exposure occurs.

Evaluation of indoor and outdoor inhalation routes of exposure indicates that outdoor inhalation is rarely the most critical route of exposure. Hence outdoor inhalation pathway is not quantitatively evaluated except for the surficial soil.

To quantitatively evaluate the indoor inhalation pathway, indoor air concentrations may be measured and compared with target indoor air levels. It is anticipated that indoor air measurements will be performed at very few sites due to several technical difficulties associated with accurately measuring the indoor air concentration contributed by soil and/or groundwater impacts. An evaluation should be performed to determine the necessity of taking air samples at a site. Recent complaints regarding vapors in enclosed spaces or outside of buildings, which might be contributed by soil and/or groundwater contamination, can serve as a justification to perform indoor air measurements. Such cases shall be evaluated under tier 2.

In the absence of indoor air measurements, mathematical models are used to relate the allowable indoor air concentrations with the soil/groundwater concentrations or soil vapor concentrations.

There is considerable controversy about the quantitative evaluation of this pathway and we may want to discuss this further. It is anticipated that the quantitative evaluation of this pathway will evolve over time.

3.4.2 Pathways for Surficial Soils (0 - 3 feet below ground surface)

Surficial soils are defined as soils extending from the surface to three feet below ground surface. The exposure pathways associated with impacted surficial soil include:

- Leaching to groundwater and current and potential use of groundwater;
- Leaching to groundwater and subsequent migration to a surface water body;
- Ingestion of soil,
- Dermal contact with soil, and
- Outdoor inhalation from soil.

To evaluate these pathways, sufficient surficial soil samples should be obtained from the impacted area. These measured concentrations are used to estimate the representative concentration(s) that are compared to the surficial soil target levels.

3.4.3 Pathways for Subsurface Soils (3 feet below ground surface to the water table)

Subsurface soils are defined as soils from three feet below ground surface to the water table. The exposure pathways associated with subsurface soils include:

- Indoor inhalation of vapor emissions;
- Leaching to groundwater and potential use of groundwater; and
- Leaching of groundwater and subsequent migration to a surface water body.

To evaluate these pathways, sufficient subsurface soil samples should be taken in the impacted area. Representative subsurface soil concentrations are then compared with the target levels developed for this pathway.

It is important to note that no distinction is made between the surface and subsurface soil for the construction worker. Instead dermal contact, accidental ingestion, and outdoor inhalation of soil vapors are considered complete routes of exposure for the construction worker.

3.4.4 Pathways for Groundwater

Exposure pathways for the impacted groundwater include:

- Indoor inhalation of vapor emissions; and
- Current and potential use of groundwater onsite or offsite.

To evaluate these pathways sufficient groundwater samples should be obtained onsite and offsite, as appropriate. The representative groundwater concentrations are then compared with the target concentrations developed for these pathways.

3.4.5 Pathways for Surface Water and Sediments

Exposure factors for surface water include:

- *Ingestion of surface water;*

- *Contact with surface water (ingestion, inhalation of vapors, and dermal contact);*
- *Ingestion of aquatic flora and fauna; and*
- *Contact with sediments.*

These pathways need not be evaluated individually for surface waters for which target levels are available. Refer to Section 3.9 for additional information regarding the protection of surface water bodies.

3.4.6 Other Pathways and Routes of Exposure

Other routes of exposure, such as ingestion of produce grown in impacted soils, or use of groundwater for irrigation purposes should be evaluated based on site-specifc considerations. The owner or operator shall contact the MDNR for further guidance related to the quantitative evaluation of this pathway.

3.5 EXPOSURE MODEL (EM)

For tier 1 and tier 2 evaluation, information about the land use, AULs, receptors, pathways is used to develop exposure model(s) for the site. The EM shows the media from which COCs are released (surficial soils, subsurface soils, groundwater, surface water), transport mechanisms for the COCs from each media (leaching, groundwater transport, volatilization, etc.), receptors of concern (residents, non-residential workers, ecological, surface water) and exposure routes (inhalation, ingestion, dermal contact, etc.) that are complete. The EM requires a basic understanding of the following characteristics:

- *Physical concentrations and distribution of the COCs obtained during site characterization,*
- *Factors affecting chemical transport,*
- *Potential for a chemical to reach a receptor, and*
- *Existing AULs and/or engineering controls.*

For tier 2, a qualitative evaluation must be performed to identify the mechanisms by which COCs will move from affected source media to the ***point of exposure (POE)*** *where contact with the receptor occurs. If this migration or contact is not possible (e.g., due to engineering controls or AULs) under current and most likely future land use conditions, the site-specific COC concentrations will not pose risk.*

The responsible party shall clearly document all the source-pathway-receptor-route combinations and present clear justification for deciding if the pathway is complete or *not complete. Remember that there may be multiple EMs if multiple offsite properties are impacted or if the impacted property is large or different activities occur across the property.*

3.6 POINT OF EXPOSURE AND POINT OF DEMONSTRATION

The POE is the location where a receptor comes in contact with COCs under current and the most likely future conditions. A separate POE is associated with each complete route of exposure identified in the EM (refer to Section 3.5). For direct routes of exposure, the POE is located at the source of the COCs. For example, for the ingestion of surface soil, the POE is at the same location as the soil source. For indirect routes of exposure, the POE and the source of COCs are physically separate. For example, for the case of indoor inhalation of vapors from soil, the POE is inside the building (the breathing space) whereas the source is the soil below the building. For the protection of groundwater pathway, refer to Section 3.8 for the location of the POE.

Thus, for each complete route of exposure, the responsible party must identify the source and the POE.

*A **point of demonstration (POD)** is a concentration measuring point located between the source and the POE. The POD could be located in any media e.g. soil, groundwater, soil vapor, etc. Target levels are developed for the POD to ensure that the concentrations at the POE do not exceed the target level at the POE. Typically, the target levels at the POD are higher than the target level at the POE. For example, for the protection of groundwater, the POD well serves as a sentry or guard well for the protection of the POE. Depending on site-specific conditions multiple PODs may be selected.*

3.7 CALCULATION OF RISK BASED TARGET LEVELS

The calculation of risk based target levels requires quantitative values of (i) target risk levels, (ii) chemical-specific toxicological factors, (iii) receptor-specific exposure factors, (iv) fate and transport parameters, (v) physical and chemical properties of the COCs, and (vi) mathematical models. Each of these factors is discussed below.

3.7.1 Target Risk Level

A risk-based decision making process requires the specification of target or acceptable risk level for both carcinogenic and non-carcinogenic adverse health effects. For carcinogenic effects, risk is quantified using the ***individual excess lifetime cancer risk (IELCR)*** that represents an increase in the probability of an individual developing cancer due to exposure to a specific COC and a route of exposure. For non-carcinogenic effects, risk is quantified using a ***hazard quotient (HQ)*** that represents the ratio of the estimated dose for a chemical and a route of exposure to the reference or allowable dose. When a receptor is exposed to multiple chemicals and multiple routes of exposure, individual HQs may be added together to estimate the ***Hazard Index (HI).*** Thus a HI is the sum of HQs. Ideally the HQs should be added together only if the COCs affect the same target organ or have the same adverse health effect. At a site, a receptor may be exposed to multiple chemicals and multiple routes of exposure in which case the acceptable risk level shall account for the effect of simultaneous exposure to multiple chemicals and multiple routes of exposure.

Based on the above the key policy choices related to the specification of target risk level are:

1. The target IELCR and HQ,
2. The specifc method to be used to account for the additivity of risk from simultaneous exposure to multiple chemicals and through multiple routes of exposure, and
3. The specific chemicals and pathways to be included in the calculation of target risk.

Each of these policy choices is discussed below:

1. An IELCR of 1×10^{-5} for each carcinogenic chemical and all route of exposure other than groundwater protection. The Hazard Index for all routes of exposure other than groundwater protection of 1 is used for each tier.
2. The cummulative (all COCs, all media) IELCR must not exceed 1×10^{-4} . For non-carcinogenic risk, the HI for each target organ must not exceed 1.0.
3. When comparing the site concentrations with the DTLs, the DTLs for individual chemicals need not be adjusted if the total number of carcinogenic COCs are less than 10. However, for non-carcinogenic risk the additivity of risk will have to be considered to ensure that the HI does not exceed 1.0 for individual target organs. Considerable flexibitiy will be provided to the responsible party to develop site-specific clean-up levels to achieve the HI of 1.0.
4. In calculating the cummulative risk, the exposure and risk due to the domestic use (ingestion and inhalation exposures) of water or groundwater protection will not be included. Further risk and target levels will be calculated for each exposure pathway, i.e. ingestion, dermal contact and inhalation and not by combining these pathways.
5. For groundwater the target concentration at the POE would be the MCL. In the absence of an MCL, ground water concentration at the POE will be calculated using the target risk of 1X10-5 and HI of 1.0, per item 1 above, using the ingestion of water and inhalation due to domestic use of water.

At sites where there may be concerns related to the stringency of these levels relative to EPA recommended levels, adjustments may have to be made.

3.7.2 Quantitative Toxicity Factors

The toxicity of chemicals is quantified using slope factors (or potency value) for chemicals with carcinogenic adverse health effects. For chemicals that cause non-carcinogenic adverse health effects, toxicity is typically quantified by reference dose. For chemicals where the toxicity is quantified using reference concentration or unit risk factors, equivalent reference dose and slope factors may be calculated.

Toxicity values for each tier are discussed below:

DTLs: MDNR will use default values to be included in the guidance document,
Tier 1: MDNR will use the same values used to develop DTLs, and
Tier 2: May use alternative values with approval of MDNR.

For tier 2 toxicity values, consult the following sources in the order listed:

- MDNR
- ***Integrated Risk Information System (IRIS)***,
- ***USEPA National Center for Environmental Assessment (NCEA),***
- ***Health Effects Assessment Summary Tables (HEAST),***
- Values withdrawn from IRIS, HEAST, and under review, and
- Review of literature by qualified professionals to develop toxicity factors as approved by MDNR.

3.7.3 Exposure Factors

Exposure factors describe the physiological and behavioral characteristics of the receptor. These factors include the following:

- Water ingestion rate,
- Body weight,
- Exposure duration for each route of exposure,
- Exposure frequency,
- Soil ingestion rate,
- Hourly inhalation rates,
- Exposure times for indoor inhalation,

- Exposure times for outdoor inhalation for construction worker only,
- Dermal relative absorption factor,
- Skin surface area for dermal contact with soil,
- Soil-skin adherence factor, and
- Oral relative absorption factor.

The exposure factors are typically estimated based on literature, and site-specific measurements are not obtained. Exposure factors for each tier are presented below:

DTLs: MDNR will use default values to be included in the guidance document,
Tier 1: MDNR will use the same values used to develop DTLs,
Tier 2: Alternative site-specific values may be used with appropriate justification and approval of MDNR.

3.7.4 Fate and Transport Parameters

Fate and transport parameters are necessary to estimate the target levels for the indirect routes of exposure. These factors characterize the physical site properties such as depth to groundwater, soil porosity, and infiltration rate at a site. The specific values used depend on the fate and transport models. The fate and transport parameters to be used depends on:

DTLs: MDNR will use default values to be included in the guidance document,
Tier 1: MDNR will use the same values used to develop DTLs,
Tier 2: Alternative site-specific values may be used with appropriate justification and approval of MDNR. These values may also depend on the specifics of the model used.

3.7.5 Physical and Chemical Properties of the COCs

The development of target levels requires selected physical and chemical properties of the COCs, e.g. solubility, diffusion coefficient, adsorption coefficient. Several of these values are experimentally determined and their values differ from reference to reference. The following physical chemical values will be used:

DTLs: MDNR will use default values to be included in the guidance document,
Tier 1: MDNR will use the same values used to develop DTLs,
Tier 2: Alternative site-specific values may be used with appropriate justification and approval of MDNR.

3.7.6 Mathematical Models

Two types of models or equations, namely (i) the uptake equations, and (ii) the fate and transport models, are required to calculate the target levels. For DTLs and tier 1, the MDNR has selected the following fate and transport models:

Indoor Inhalation of Volatile Emissions from Soil and Water: This pathway requires (i) an emission model, and (ii) indoor air mixing model. These models are combined together and included in the Johnson and Ettinger Model presented in ASTM (1995).

Surficial Soil Outdoor Inhalation (construction worker only): This pathway also requires an (i) emission model for vapors, (ii) emission model for particulates, and (iii) an outdoor air mixing model. The vapor emission model used is based on the volatilization model developed by Jury et al (1984) for infinite source, the outdoor mixing model is based on Cowherd's model, and the outdoor air mixing model is based on a simplified form of the Gaussian Dispersion model. These models are presented in the Soil Screening Guidance Document (U.S.EPA, 1996).

Leaching to Groundwater: This pathway requires and equilibrium conversion algorithm to (i) convert the soil concentrations to leachate concentration, and (ii) mix the leachate with the regional groundwater as included in Soil Screening Guidance Document (USEPA, 1996). Summer's model will be used for mixing of the leachate with the groundwater.

Horizontal Migration in Groundwater: The Domenico's steady-state infinite source model is used to quantify the downgradient migration of chemicals. For RE-2 evaluation, a biodegradation rate, if it can be justified based on site specific conditions may be used with prior approval of MDNR.

Unsaturated Zone Transport: For the calculation of look up values, the following dilution attenuation factors will be used:

Depth to groundwater of less than 20 feet,	DAF = 1
Depth to groundwater 20-50 feet,	DAF = 2
Depth to groundwater > 50 feet,	DAF = 4

Note for the tier 2 option, alternative models with the approval of MDNR may be used.

3.8 GROUNDWATER PROTECTION

3.8.1 Objectives of Groundwater Protection

Impacts to groundwater and potential exposures via the groundwater ingestion pathway are of significant concern since several areas of the state obtain their drinking water from groundwater sources. The evaluation process and groundwater protection measures are intended to be used in cases where groundwater has been impacted or is likely to be impacted by site-specific chemical releases. This process has the following primary objectives:

- Be protective of human health and the environment,
- Recognize that all subsurface water does not constitute a potential drinking water source,
- Recognize and be protective of property and groundwater rights,
- Recognize the three dimensional nature of groundwater, and
- Allow consideration of technical impracticability in groundwater remedy selection.

The process consists of determining whether the groundwater use pathway is complete (i) under current conditions, and/or (ii) future conditions. The process is schematically presented in Figure 3-1. This determination is based on the following factors that must consider each groundwater zone:

Current Conditions:

1. Existence of current water use wells near the site, and
2. Reasonable probability of impact.

Future Conditions:

1. Institutional Controls,
2. Suitability of groundwater use as determined by natural quality and yield,
3. Sole source determination,
4. Probability of future use determination based on a consideration of following factors using a weight of evidence approach
    a. Current groundwater use patterns
    b. Availability of alternative water supplies,
    c. Institutional controls,
    d. Urban development considerations, and
    e. Aquifer capacity limitations.

If it is determined that this pathway is not complete under current conditions and site conditions eliminate any reasonable probability that the groundwater will serve as a water supply source, no further evaluation of groundwater use pathway will be required. If it is determined that site related chemicals could impact groundwater quality in an existing well, or in a zone with a reasonable probability of future use, the pathway will have to be evaluated. This evaluation will require the determination of the nearest (i) point of exposure (POE), and (ii) risk based target levels at the POE.

Note irrespective of the results of Step 1, two other conditions have to be met. These are:

1. Consideration of all other pathways associated with the current or potential future impacts to groundwater zones. Examples of these impacts include but are not limited to (i) discharge to a surface, or (ii) volatilization and subsequent inhalation of vapors from groundwater.

2. In all cases sufficient steps should be taken to ensure that the plume is not expanding.

In addition to the above, the subgroup presented several case studies to illustrate the application of the above concepts.

3.8.2 Concentrations for Groundwater Ingestion

MCLs are target, health-protective concentrations promulgated by the USEPA and adopted by the State of Missouri for the protection of drinking water and specified groundwater resources. For COC the target concentrations for groundwater ingestion are equal to the MCL or health advisories, where available. For chemicals that do not have either an MCL or health advisories, use risk based target levels considering the residential use of water including ingestion and inhalation from domestic water use.

3.9 SURFACE WATER AND STREAM PROTECTION

Requires further discussion

3.9.1 Surface Water Quality Standards

Need further discussion.

3.10 ESTIMATING POINT OF DEMONSTRATION WELL CONCENTRATIONS

As a part of this process, it is necessary to designate point of demonstration (POD) wells either onsite and/or offsite to confirm that the concentrations at a selected point of *exposure (POE) do not exceed the target levels in the groundwater or in a surface water if applicable. Monitoring of POD wells must occur, and the data obtained from the monitoring of those wells must be utilized as representative concentrations to compare with calculated tier 1 or tier 2 target levels. Monitoring of POD wells will be continued until the concentrations in the demonstration wells stabilize below the calculated demonstration well target levels.*

3.11 NUISANCE CONDITIONS AND FREE PRODUCT

In addition to the evaluation of human health risk and ecological risks, each site should also be evaluated qualitatively for the existence of nuisance conditions including but not limited to objectionable taste or odor in groundwater, aesthetic problems with resurfacing groundwater, and odor from soils remaining in place. This evaluation would be documented and reported.

Free product (nonaqueous phase liquids at saturations corresponding to potential mobility) shall be removed to the maximum extent practicable. The degree of removal constituting the "maximum extent practicable" is a site-specific determination and does not equate to a single "NAPL thickness in well" measurement uniformly applied to all sites regardless of site and NAPL characteristics.

3.12 ECOLOGICAL RISK EVALUATION

A key objective of the RBDM process is to manage sites so that they are protective of human health as well as the environment. Exposures to ecological receptors, threatened and endangered species, habitats, wetlands and other sensitive environments must be thoroughly evaluated.

A tiered process has been developed to incorporate ecological protection in the RBDM process and includes the following:

<u>Tier 1 Ecological Evaluation</u> will be performed to identify whether any ecological issues exist at the site. Specifically, tier 1 ecological evaluation requires the completion of two checklists included in their report (Appendix G). Each checklist consists of a series of questions that can be completed by an experienced environmental professional – not necessarily by a trained biologist or an ecologist.

Checklist 1 consists of eight questions and is designed to determine whether an ecological receptor exists near the site. The questions are designed such that if the answer to all the questions is negative, no further ecological evaluation will be necessary. However, if the answer to any one of the eight questions is positive, the second checklist has to be completed. This checklist consists of seven key questions to determine whether site related COCs can migrate to the ecological receptors through any pathway. If there is no pathway by which chemicals can migrate to the ecological receptors, i.e. the answer to all the questions is negative, no further evaluation is necessary. If the answer to any one of these questions in positive, a tier 2 ecological evaluation is necessary.

Tier 2 Ecological Evaluation will include comparison of representative concentrations with ecological threshold values available in literature. A hierarchy of sources from where threshold values may be obtained include:

- Oklahoma Water Quality Standard,
- EPA Ecotox thresholds, and
- ORNL values.

If comparison of site-specific soil, surface water, and sediment values indicates that the threshold values are exceeded, adopted either a Tier 3 ecological evaluation will have to be completed or the tabulated values as cleanup goals. If the latter option is selected, a RMP shall be submitted, approved by MDNR, and implemented in a timely manner.

Tier 3 Ecological Evaluation will include a detailed site-specific evaluation as per the current U.S. EPA guidance on performing ecological risk evaluation. Tier 3 evaluation will require the development of a site-specific detailed work plan and approval by MDNR prior to its implementation.

In addition to developing the above tiered process, this subgroup also provided definitions of several terms that will be incorporated into the guidance document.

3.13 INSTITUTIONAL CONTROLS

Activity Use Limitations (AULs) are designed to ensure that the pathways that may pose an unacceptable risk and are considered incomplete, remain incomplete for as long as the residual concentrations make the risk from the pathway unacceptable. AULs are also used to ensure that the assumptions made in the development of target levels are not violated under current and future conditions. Thus, AULs are an integral part of the RBDM process. The judicious application of AULs can facilitate property transaction, redevelopment and beneficial reuse of Brownfields and other contaminated properties.

Activity Use Limitations shall apply whenever the residual media-specific concentrations exceed the residential land use (unrestricted land use) levels. MDNR recognizes that a variety of AULs are available that may be used. In all cases the AULs shall be durable, reliable, enforceable, and consistent with the risk posed by the contaminants. The subgroup report provides additional details of the AUL process.

3.14 NOTIFICATION REQUIREMENT

We need to discuss this.

3.15 REPRESENTATIVE CONCENTRATION

Application of this process (in the backward mode) results in target levels for each complete pathway identified in the exposure model and each chemical of concern (COC). For site-specific risk management decisions, these target concentrations have to be compared with appropriate representative concentrations.

The calculation of representative concentrations is complicated by several factors. These include (i) spatial variability in the concentrations, (ii) temporal variability in the concentrations, and (iii) lack of sufficient site-specific concentration data. To account for these factors, several methodologies have been used to estimate the representative concentrations. These include (i) maximum, (ii) the upper bound of the 95th percentile one or two sided confidence interval about the mean, (iii) arithmetic average, (iv) area-weighted average, (v) depth-weighted average, (vi) geometric average, and (vii) volumetric average (very rarely used) concentration. Associated with each of these concentrations are certain advantages and disadvantages and there is no uniformly accepted methodology to estimate the representative concentration. Thus the application of a particular methodology to estimate a representative concentration is ultimately a policy choice.

<u>Since there may be several complete pathways at a site, several representative concentrations, one for each complete pathway, have to be estimated</u>. The effort necessary to calculate the representative concentrations for certain complete pathways can be avoided if the maximum media-specific concentration does not exceed the target level.

The specific method to be used to compute the representative concentrations is presented in the Representative Concentrations Work Group Report. Recommendations are summarized in Table 3-2.

3.16 DELINEATION OF IMPACTS

Site characterization activities shall be performed to delineate the vertical and horizontal extent of impacts. Typically site characterization proceeds outwards from known or suspected source areas. Soil, groundwater and soil vapor sampling shall be continued until the extents of impacts have been delineated to the default target levels. Where the site has chemicals for which DTLs are not available, the RP shall contact MDNR.

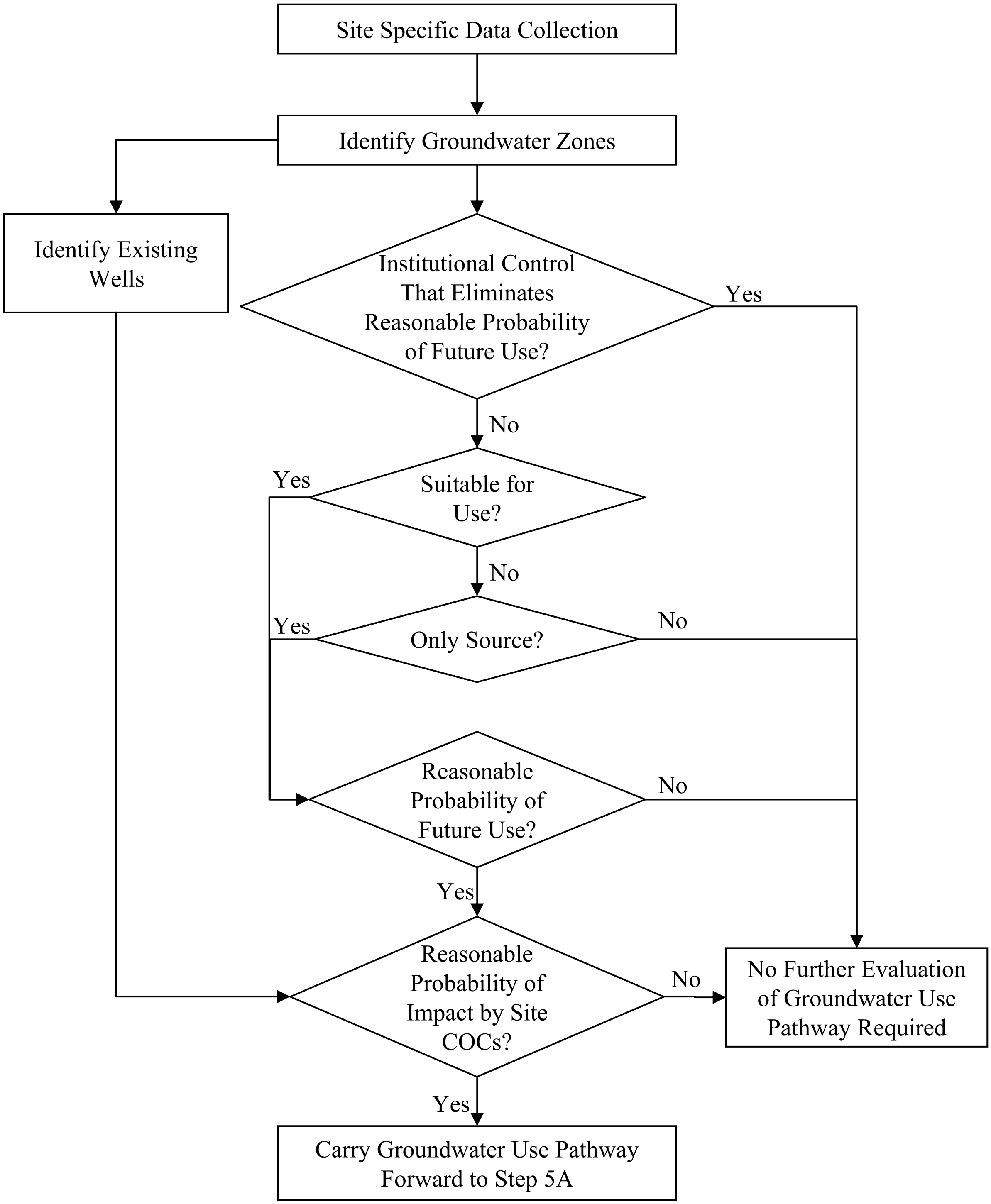
At sites where multiple sources exist and the chemicals have not commingled, delineation as defined above may have to be performed for each source unless approved otherwise by MDNR.

TABLE 3-6
REPRESENTATIVE CONCENTRATION RECOMMENDATIONS

ROUTE OF EXPOSURE	REPRESENTATIVE CONCENTRATION	NOTES
Ingestion of chemicals in groundwater due to leaching from surficial soil	Area-weighted average	
Accidental ingestion of soil, outdoor inhalation of vapors and particulate from surficial soil emissions, and dermal contact with surficial soil	Area-weighted average / Maximum *	* If a child could reasonably contact with the surficial soil in the future, (i.e. no restrictions made to future land use). (DNR would look at re-defining the depth of surficial soil in this case.)
Ingestion of chemicals in groundwater due to leaching from subsurface soil	Volume weighted average / Arithmetic average *	* Where not many samples exist such as at smaller sites.
Indoor inhalation of vapor emissions from subsurface soil	Area-weighted average	
Accidental ingestion of soil, outdoor inhalation of vapors and particulate from surficial soil emissions, and dermal contact with soil - Construction worker only	Volume weighted average / Maximum	
Outdoor inhalation of vapors from groundwater - Construction worker only	Area-weighted average	
Ingestion of groundwater	Arithmetic average of most recent consecutive eight measurements, of which no two shall be less than 3 months apart.	For wells that have static concentrations
	Arithmetic average of most recent consecutive six measurements, of which no two shall be less than 3 months apart.	For wells that have decreasing concentrations
Indoor inhalation of vapor emissions from groundwater	Area-weighted average	
Dermal contact with groundwater		

Note:
Consideration of the pathway in italics has not been agreed upon.

FIGURE 3-1. SITE CONCEPTUAL MODEL
DOMESTIC CONSUMPTION OF GROUNDWATER EXPOSURE PATHWAY ANALYSIS



NOTE:
1. In this chart, "use" refers to domestic consumption.
2. The analysis embodied in the chart is performed for each groundwater zone of interest. The conclusion of the analysis (the groundwater use pathway is either carried forward for additional consideration, or no further evaluation of the pathway is required) applies to the individual groundwater zone under analysis. Different conclusions may apply to different groundwater zones at a given site.
3. The attributes of an institutional control that would be sufficient to "eliminate reasonable probability of future use", and that would be sufficient to conclude "no further evaluation of groundwater use pathway required" at this step in the site conceptual model process, have yet to be defined. It is anticipated that the institutional control subgroup will address this topic.

APPENDIX A
LAND USE CONSIDERATIONS

Land Use

Human exposure risks are dependent on land use. To determine appropriate cleanup levels for a site, one must first determine what the current and reasonably likely future use(s) of the property are, in conjunction with the remaining contaminates of concern.

The current and recent uses of the property and surrounding area must be clearly identified on maps and included in the site characterization report to MDNR. Reasonable judgements should be made concerning how far beyond the boundaries of the contaminated site one should identify land uses; as a general rule, the maps should extend 500-1000 feet beyond the area likely impacted by the chemicals of concern.

Current and reasonably likely future land use must be categorized as either “residential” or “non-residential.” The “residential” category results in lower cleanup target levels. If one develops a risk management plan based on the current or likely future use being “non-residential,” an appropriate Activity and Use Limitation (AUL) may be required. AULs may include appropriate institutional controls and/or engineering controls.

While it is not possible to identify every scenario in this document, the following guidelines are intended to assist in making the land use determination:

- **Residential (Unrestricted)**– Includes land uses where persons can be expected to reside for
  more than 8 hours a day, 7 days a week, such as homes, apartments, hospitals, nursing homes, schools, childcare centers, farms with houses.

- **Non-Residential** – Includes land uses where persons can be expected to be onsite less than 10 hours a day, and absent on weekends and holidays, such as retail facilities, industrial and manufacturing operations, fleet operations, hotels and motels.

(**Note:** When a planned development for a contaminated site includes a multi-story building, or mixed use, the presence of a day care facility or apartments on an upper floor does not necessarily mean the land use is “residential.” Reasonable assumptions concerning exposures on the ground floor of the building should be used to develop cleanup target levels.)

Issue to Consider:

- The identification of the extent of the boundaries of property surrounding the contaminated site (See second paragraph above) may be determined once the group defines the Point of Compliance and the Point of Exposure.

APPENDIX B
RISK ADDITIVITY AND TARGET RISKS

Risk Additivity and Target Levels Subgroup
Draft Recommendations of November 6, 2002

I. Introduction

This document summarizes the available metrics, regulatory policy issues, technical issues and subgroup recommendations associated with the assessment of health risk due to exposure to multiple chemicals via multiple routes of exposure.

Typically, a quantitative estimate of health risk is calculated for a carcinogenic toxicant and a noncarcinogenic toxicant using the following formulas:

> Carcinogenic Risk (called Incremental Excess Lifetime Cancer Risk or IELCR) = [Estimated Dose] x [Slope Factor]
>
> Noncarcinogenic Risk (called Hazard Quotient or HQ) = [Estimated Dose] / [Reference Dose].

Slope Factor is the 95% upper bound of the estimated slope of the cancer dose-response curve (i.e., the increase in tumor rate per daily unit dose). For U.S. regulatory purposes, all tumors (malignant and benign) are considered to be potentially cancerous (malignant). Although the Slope Factor may simply reflect an increase in the variability seen in the animal tumor data, for regulatory purposes chemicals with larger slope factor values are considered to be more potent with regard to cancer causing ability.

Reference Dose (RfD) is the level of daily exposure that is unlikely to result in toxic effects to humans, including sensitive subgroups (e.g., the very young or old), even if exposure occurs for a lifetime. In general, the RfD is estimated by dividing the lowest dose found not to produce adverse effects (NOEL) by an appropriate uncertainty factor (commonly one or more orders of magnitude). For example, if the NOEL for a chemical is determined to be 300 mg/kg/day, the RfD for that chemical might be 1/1000 of that amount (0.3 mg/kg/day).

The subgroup recommendations do not address the technical issues associated with the estimation of exposure levels.

A. Toxicant Interactions

While most chemicals are toxicologically independent in terms of the adverse effects they produce, certain chemicals interact in a number of ways that affect the degree of toxicity produced in a person (i.e., receptor) who is exposed to a mix of toxicants (Eaton & Klaassen 1996). Toxicant interactions are generally divided into four categories:

- Additivity: In this type of interaction, the total toxic effect seen is the sum of the dose-specific toxicity of each of the chemicals to which the individual is exposed (e.g., 2 + 3 = 5). Additivity is the most commonly encountered form of toxicant interaction, and most regulatory agencies assume by default that the identified chemicals of concern at a site interact in an additive manner.

Example: When a person is exposed to two organophosphate insecticides, the degree of cholinesterase inhibition seen is usually additive.

Additivity was considered by the subgroup to be important and a recommendation for handling additivity is included in this document.

- Synergism: Exposure to certain chemicals results in total toxic effect that is greater than would be expected from the simple sum of their individual dose-specific toxicities (e.g., 2 + 3 = 10) -- a phenomenon known as synergism. It should be appreciated that the potential combinations of toxicants and dosage combinations are almost limitless, and it should not be surprising that this toxicological phenomenon has not been exhaustively studied. It should be emphasized, however, that with regard to the chemicals commonly found at contaminated environmental sites, relatively few examples of this type of toxicant interaction have been identified and synergy is therefore generally not addressed by regulatory agencies.

  Example: Ethyl alcohol and carbon tetrachloride are both toxic to the liver, but when administered together, they produce much more liver injury than when each is given alone.

  Synergism was considered by the subgroup. This document does not, however, advocate attempting to address synergism in the context of the proposed rule due to the overall complexity of the issues associated with it, the lack of concrete examples/information applicable to contaminated sites and the general expectation that synergistic effects will likely not be the primary risk driver at the majority of sites. As the overall body of knowledge increases with respect to this topic in the future (e.g., endocrine disrupting chemicals), it may need to be revisited for possible incorporation into the risk-based decision-making process.

- Potentiation: Potentiation refers to the situation in which exposure to a chemical that is not toxic to a certain organ or system makes the dose-specific toxic effect of another chemical much more severe than expected (e.g., 0 + 2 = 10). Like phenomenon of synergism discussed above, potentiation appears to be relatively uncommon with regard to the environmental contaminants usually encountered, and is generally not addressed by regulatory agencies.

  Example: Isopropyl alcohol is not toxic to the liver, but when administered with carbon tetrachloride the degree of liver injury is greater than when carbon tetrachloride is given alone

  Potentiation was considered by the subgroup. Similar to the issue of synergism, this document does not advocate attempting to address potentiation in the context of the proposed rule due to the overall complexity of the issues associated with it, the lack of concrete examples/information applicable to contaminated sites and the general expectation that potentiation effects will likely not be the primary risk driver at the majority of sites. As the overall body of knowledge increases with respect to this topic in the future (e.g., endocrine disrupting chemicals), it may need to be revisited for possible incorporation into the risk-based decision-making process.

- Antagonism: In this type of interaction, exposure of an individual to a mixture of chemicals produces less toxicity than would be expected from the known dose-specific toxicity of each (e.g., 2 + 3 = 1). While known examples of toxicological antagonism are more common than those for synergism and potentiation, it would be difficult, if not impossible, to predict the magnitude of dose-specific antagonistic effect expected in a mixture of toxicants. From a regulatory perspective, antagonism is generally not addressed because of long-standing regulatory policies that errors introduced by an adopted assumption or procedure should be in a direction that protects human health (i.e., health-conservative). Clearly, an unequivocal technical argument could be made that the total health risk posed by a mixture of chemicals is not being underestimated if antagonism is ignored.

  Example: Because toluene and benzene compete for the same metabolic enzyme, coadministration of toluene and benzene results in less benzene being converted into toxic derivatives and therefore, less toxicity to the blood forming organs (dispositional antagonism). Dimercaprol (BAL) is used clinically to chelate (tightly bind) heavy metals such as arsenic, mercury and lead, thereby reducing their toxicity (chemical antagonism). Chemically induced convulsions may be controlled by administering an anticonvulsant drug such as diazepam (functional antagonism). Oxygen is administered in cases of carbon monoxide poisoning to displace the carbon monoxide that is bound to receptors on the hemoglobin molecule (receptor antagonism).

Each of the above phenomena is dose-dependent and reflects the complexities of biological systems. It would not be unexpected that at one dose level, Chemical A will show toxicity that is additive when administered with a specific dose of Chemical B. A higher dose of chemical A might produce a combined effect consistent with potentiation, while at even higher doses it produces a combined effect of antagonism. In view the above considerations, the subgroup recommends that the risk-based strategy operate on the assumption that exposures to the Chemicals of Concern (COCs) at an impacted area will produce health risks in an additive manner. This regulatory assumption is considered to be health conservative, yet reasonable.

II. Approaches to the Evaluation of Combined Health Risks

At a given site, a receptor may be exposed to multiple chemicals, in multiple media (soil, groundwater), and by multiple routes of exposure (inhalation, ingestion, dermal contact). Assuming that toxicants interact additively, measures of cumulative cancer and noncancer risk can be calculated in a number of ways. These include:

- Each COC by each medium, by each complete exposure pathway.
- Each COC by each route of exposure (e.g., inhalation) having one or more complete exposure pathways (e.g., vapor from soil + vapor from groundwater).
- Each COC by each medium, by all complete exposure pathways.
- Each COC in all media, by all complete exposure pathways.
- All COCs by each medium, by each complete exposure pathway.
- All COCs by each route of exposure having one or more complete exposure pathways
- All COCs by each medium, by all complete exposure pathways
- All COCs in all media, by all complete exposure pathways.

The objective of the regulatory risk assessment process is to ensure that people will not be exposed to toxicants at levels that pose unacceptable levels of carcinogenic and/or noncarcinogenic risk. The USEPA (OSWER Directive 9355.0-30; 1991) states, "Where the cumulative carcinogenic site risk to an individual based on an RME scenario for the current and future use is less than 1.0E-4, and the noncarcinogenic hazard quotient (index) is less than one, remedial action is generally not warranted." Most of the states reviewed by the subgroup have defined acceptable lifetime incremental cancer risk in the range of 1.0E-6 (one in 1 million) to 1.0E-4 (one in 10,000), and an acceptable noncarcinogenic hazard quotient (index) in the range of 0.2 to 10 depending on the cumulative risk metric used. All states reserve the right to require more stringent acceptable risk criteria for a site, if warranted, and Missouri is no exception.

III. Recommended Measures of Cumulative Health Risk

All of the possible measures of cumulative risk noted above need not be calculated for every site, however, three of these measures appear to be particularly appropriate from a regulatory context:

- COC-Specific Risk for Each Medium: Because site investigation and corrective action at environmental sites focus on the level of a contaminant in each environmental medium (i.e., surface soil, groundwater, etc.), health risks posed by each COC in a medium at a site should first be evaluated individually. No toxicant in a medium may pose an individual health risk greater than the acceptable risk criteria for carcinogens or noncarcinogens, considering all complete exposure pathways for that medium. It should be noted that it is a variant of this risk measure that is used to calculate the cleanup target concentration for each COC in a medium.

- Cumulative Risk for each Medium: The medium-specific cumulative risk should then be determined by adding the individual risks of all COCs in that medium (i.e., by assuming that their individual toxicities are additive). No medium may pose a total risk greater than the acceptable risk criteria for carcinogens or noncarcinogens, considering all complete exposure pathways for that medium. All COCs in each medium are combined regardless of target organ specificity. If the cumulative risk for a medium exceeds the above criteria, then total site risk for noncarcinogenic compounds may be broken down on an organ-specific basis (i.e., by considering only those COCs affecting the same target organ or system). This approach, while allowing additional flexibility for noncarcinogens may be technically difficult and potentially expensive. For example, EPA uses a health conservative method to calculate the Reference Dose (RfD) for a toxicant based on the health effect(s) seen at the lowest toxic dose administered in a scientifically credible study. EPA describes this process in their Integrated Risk Information System (IRIS) summary. Suppose for discussion purposes that hyperactivity (neurotoxic effect?) in exposed rats was judged by EPA scientists to be the most sensitive indicator of a chemical's toxicity and was used as the basis for calculating the RfD. At higher doses, suppose that adverse effects in other target organs (e.g., microscopic changes in the kidney, adrenal, and in an organ called the Zymbal gland that is unique to the rat) were seen in that same study. The IRIS lists these effects, but the RfD (based on hyperactivity) overestimates the risk of these effects (again, a health conservative procedure). Toxic effects in another target organ (e.g., toxicity to the ovary seen at the only dose tested in hamsters) may have been reported in another scientifically credible study not used by EPA for calculating the RfD, and this target organ may not be discussed at all in the IRIS summary. Since it is not readily available in IRIS, it is unlikely to be addressed in a risk assessment (a situation that may not be health conservative). In addition, there are RfDs that are based on findings that are not organ-specific (e.g., decreased body weight). Other RfDs are based on the observation that the highest dose tested did not produce adverse health effects in the study animal. These factors, and more, highlight the complexities that underlie the risk assessment process. In allowing flexibility for noncarcinogens, it must demonstrated to the satisfaction of the Department that the target organs and systems assumed when subdividing the total site risk are technically appropriate for the COCs at issue in each medium.

- Total Site Risk: Since the primary regulatory objective of the risk assessment process is to protect health, it must be demonstrate that the total cancer and noncancer risk to each receptor (i.e., the sum of risk posed by all COCs from all complete or potentially complete exposure pathways) does not exceed the acceptable risk criteria established by the Department. In situations where total site risk exceeds these criteria, the subgroup believes that substantial flexibility should be retained with respect to reducing total site risk to an acceptable level.

These three risk metrics outlined above appear to satisfy the regulatory objectives of the risk-based decision-making process. While it is possible to calculate other risk metrics, doing so appears to be of questionable value in terms of making technical and regulatory decisions.

IV. Overall Subgroup Recommendations

A target risk of 1.0E-5 for individual carcinogenic COCs and a Hazard Quotient (HQ) of 1.0 is recommended at all levels for contaminated soil (i.e., REI, II & III; Tier I, II & III or however those levels may ultimately be defined). In addition, cumulative carcinogenic risk of 1.0E-4 must not be exceeded at any level for contaminated soil. In addressing cumulative noncarcinogenic risk, a Hazard Index (HI) greater than 1.0 could be addressed by simply taking actions to lower that risk to an acceptable level, however, that is only one option. In the presence of multiple contaminants, the subgroup recommends retaining the option to allow the HI to be broken out by target organ(s). If it can be demonstrated that the HI $\leq$ 1.0, for each target organ then further evaluation will not typically be warranted. If the HI $\geq$ 1.0 for the target organ(s), then further evaluation and/or remediation will likely be required to address noncarcinogenic risk.

In order to facilitate assessment of additivity/cumulative risk it is recommended that the soil exposures be broken down by pathway (i.e., inhalation, dermal, ingestion). This deviates from the methodology currently employed in the CALM document and that used by most, if not all other states and EPA Regions, whereby the pathways are combined into one number for what appears to be the sake of mathematical convenience. In considering this issue, the EPA Region IX PRG tables currently utilized by Region VII were reviewed. Two observations on this topic emerged. In the majority of cases, the risk associated with one particular pathway (e.g., inhalation) is the driver (i.e., the risks are not uniformly distributed amongst the pathways) and the "driving" pathway may vary by COC. Also, depending on the relative magnitude of the risks posed by each pathway, the combined number presented in the Region IX PRG tables may simply be the number represented by a single pathway or the number may be adjusted slightly based on the contribution of other pathways.

At the RE1/Tier 1 (i.e., Look-up Table) level, soil contaminant levels measured at a site would be compared to individual calculated COC levels. If the number of COCs at the site is 10 or less, carcinogenic additivity would not need to be considered since mathematically the total cumulative carcinogenic risk could not exceed 1.0E-4, if all COCs were at or below the 1.0E-5 level (i.e., 10 x 1.0E-5 = 1.0E-4). An evaluation of carcinogenic additivity is recommended if the number of COCs exceeds 10. This same concept would not apply to multiple COCs where noncarcinogenic effects are the risk driver. Additivity would always need to be addressed in the case of multiple COCs where noncarcinogenic effects are the risk driver since there is no dual risk standard (i.e., the screening HI is 1.0). Again, the option here, in the presence of an HI that exceeds 1.0, is to evaluate by target organ(s). The recommended methodology for calculating cumulative risk is presented in Attachment 1. Attachment 1 also contains examples of how risk reduction might be achieved under the noted circumstances. It is the subgroup's recommendation that flexibility be retained in the context of the proposed rule with respect to how appropriate reductions in risk are achieved (e.g., mandating or prescribing a proportional reduction in risk across all contaminants and/or media should be avoided).

The subgroup's recommendations concerning target risk for carcinogens and noncarcinogens are within EPA's current guidelines for acceptable risk. None-the-less, EPA has expressed concerns with setting a preliminary target risk for carcinogens which is less stringent than 1.0E-6. This concern appears rooted in EPA's longstanding policy concerning use of 1.0E-6 as a "point of departure" risk level (i.e., a starting point for risk that may be (and is routinely) departed from in site-specific circumstances provided that adequate site-specific justification is developed and that the cumulative risk from the site still falls within the risk range articulated in the National Contingency Plan and EPA Guidance). This issue is also a concern with respect to certain state programs (such as Missouri's corrective action program) which have been granted EPA authorization with the expectation that those state programs will be no less stringent than EPA in their operation. The state certainly has no interest in jeopardizing its authorization or federal funding nor does the state want to artificially create any additional federal liability for facilities that are performing clean-up under state-authorized programs, hence, the recommendations noted below.

As indicated earlier in this document, all states have reserved the right with the context of their risk-based programs to require more stringent risk criteria for a site, if warranted, and Missouri is no exception. Hence, to reserve this right and address any concerns EPA may have with regard to target risk, it is recommended that one or more of the following be included in the rule: 1) overarching reservation of rights language in the "Site Applicability" or equivalent section of the rule (e.g., no less stringent language similar to what Illinois has in their law) which would address not only the target risk issue but potentially a host of other "no less stringent than federal requirements" issues as well; 2) "reservation of rights" language addressing the risk range issue for certain types of sites (e.g., RCRA) to be located in the "Risk Assessment" or equivalent section of the rule, and/or 3) inclusion of a footnote(s) to any lookup tables which reference the potential applicability of more stringent risk screening levels for carcinogens at certain types of sites and an acknowledgement that if 1E-06 is used as the guiding risk, the carcinogenic numbers in the lookup tables would need to be adjusted downward by a factor of 10.

In terms of target risk levels and additivity of risks for groundwater, the subgroup has the following recommendations. It is recommended that groundwater be considered separately from the other exposure pathways and not specifically be factored into any cumulative risk calculations at an REI/TierI (i.e., lookup table) level, although there may be reason to do so at an REIII/Tier III and, perhaps, even an REII/Tier II level. At the REI/Tier I level, most other states appear to rely on a hierarchy of existing published sources for groundwater numbers similar to Missouri's current CALM document (e.g., Maximum Contaminant Levels (MCLs) and Health Advisory Levels (HALs) under the Safe Drinking Water Act, Missouri Water Quality Standards for the protection of groundwater (MOWQS), etc.). This reliance on existing published sources appears to stem, in no small part, from the regulatory and administrative issues surrounding the use of previously-established, enforceable criteria under existing laws/regulations versus establishment of "new" numbers in rules or guidance for cleanup programs, many of which could be more stringent (depending on the target risk level) than established levels under other non-cleanup statutes/regulations. The regulatory, administrative and jurisdictional complications posed by these issues, while not insurmountable, are significant. Hence, the subgroup advocates using a similar, if not identical, approach to the way those numbers are generated in the current CALM document to establish look-up values for groundwater (GTARCs) at the RE1/Tier I level. It is certainly worth noting, however, that acceptable tap water values presented in the EPA Region IX PRG tables are based on domestic exposures from ingestion and inhalation and, in many cases, are well below the drinking water MCL for certain contaminants at a 1E-06 risk level. This stems from the fact that MCLs, while they carry a particular risk level based on ingestion and inhalation, were not originally developed on the basis of a defined, standard level of risk. It is also worth recognizing that MCLs/HALs/MOWQS do not consider the cumulative effect of other exposures to contamination (e.g., soil) related to a particular site that might be occurring to an individual. However, in the majority of cases, this may not be an issue inasmuch as an individual being exposed to contamination at a commercial or industrial site is not likely to be drinking contaminated groundwater related to that site and conversely, an individual drinking contaminated groundwater related to a site is not likely to be exposed to other contamination at that site unless, of course, that individual lives right next to his/her place of employment and is using water from a contaminated well located on their adjacent or nearby property for domestic consumption.

In the absence of established numbers for certain chemical compounds, the subgroup recollects that the larger group decided that numbers would need to be calculated based on the ingestion and inhalation routes of exposure (dermal excluded as deminimus) for domestic consumption. This approach is consistent with the broader approach employed in generating the tap water numbers contained in the EPA Region IX PRG tables. The subgroup agrees with this approach and recommends that those exposure numbers be calculated at the 1.0E-5 carcinogenic and HQ = 1.0 noncarcinogenic risk levels to be consistent with the recommended target risks for soil. Further, the subgroup recommends that, at a minimum, the ability to require assessment of the cumulative risk related to all contaminated media at a site, including groundwater, be retained at the REIII/Tier III level. This would not be an absolute requirement at that level, but could be exercised, as appropriate, at particular sites.

Though not specifically addressed here, the RE1/Tier 1 lookup tables will need to establish acceptable media transfer levels as a function of risk (i.e., protection of groundwater given the site-specific use or potential use of that groundwater based on conservative fate and transport assumptions) similar to the C_{leach} concept contained in the current CALM document and Superfund's Soil Screening Level (SSL) Guidance. Similarly, acceptable media transfer levels which address such transfers from soil and groundwater to indoor air will be necessary. As above, it is worth noting that some states have already promulgated standards for groundwater (below MCLs for some contaminants) that are based on the transfer of contaminants to indoor air. In the case of all types of media transfers, the option should be retained at all RE/Tier levels to demonstrate through site-specific testing and/or modeling what levels will be protective of human health and the environment in a media transfer context.

V. References

Eaton DL & Klaassen CD. Chapter 2: Principles of toxicology. In Klaassen CD, Amdur MO & Doull J, ed. Cassarett & Doull's Toxicology: The Basic Science of Poisons (New York: McGraw-Hill Health Professions Division, 1996), pp 13-33.

U.S. Environmental Protection Agency, Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions, Office of Solid Waste and Emergency Response, Washington DC, OSWER Directive 9355.0-30, April 22, 1991.

Attachment 1

ADDITIVITY OF RISK AND TIER 1 LOOKUP TABLES

Typically Risk Based Screening levels (Tier 1 lookup values, U.S. EPA Regional PRGs etc.) are individually calculated for each chemical and combined routes of exposure. Thus these look up values do not consider the additivity (risk from multiple chemicals) or the summation of risk (risk from a chemical related to individual exposure pathways).

If the evaluation of target risk requires the consideration of cumulative risk (i.e., additivity and summation), Tier 1 look up tables can still be used to estimate Tier 1 risk as well as Tier 1 target levels, however, doing so will involve some calculations as outlined below:

The following steps have to be implemented for each receptor:

Step 1: Determine the chemicals of concern (COCs) at the site (for example there are 'N' chemicals)
Step 2: Determine the complete routes of exposure (ROE) (for example there are 'M' ROEs)
Step 3: For each COC and ROE determine the representative concentration
Step 4: For each COC and ROE select the target level from the look up table
Step 5: Calculate site specific risk for each COC and each ROE as,

$$R_{ij} = \frac{RL \times C_{ij}}{T_{ij}}$$

Where; R_{ij} = Risk for chemical i for route of exposure j
RL = Risk level used to develop the "look up" tables
C_{ij} = Representative concentration for chemical i for route of exposure j
T_{ij} = Target level for each chemical i and each route of exposure j

Step 6: Calculate total risk at the site for each receptor by adding the risk for each COC (i.e. N chemicals) and each ROE (i.e. M ROEs)

$$R_{total} = ? ? R_{ij}$$

The above steps result in the cumulative risk at the site, together with an idea of which chemical and which pathway is contributing the most risk to the total. If the total risk exceeds the target risk, remediation and/or evaluation at the next tier level will now have to be considered. The above can help identify the most appropriate path forward and the chemicals that may require the most attention.

The above process is illustrated using a hypothetical example shown in Tables 1-3. The example assumes 3 complete routes of exposure for 4 chemicals for an on-site commercial worker.

Table 1: Representative concentrations for each chemical and each route of exposure.

CHEMICALS	ROE 1 (mg/kg)	ROE 2 (mg/kg)	ROE 3 (mg/kg)
Benzene	1.5	1.0	1.0
TCE	0.5	0.75	1.0
Hexachlorobenzene	0.25	0.5	0.5
Vinyl Chloride	0.25	0.25	5.0

Table 2: Target levels for each chemical and each route of exposure (based on risk level of 1×10^{-6}).

CHEMICALS	ROE 1 (mg/kg)	ROE 2 (mg/kg)	ROE 3 (mg/kg)
Benzene	0.5	0.25	2.0
TCE	1.0	1.0	5.0
Hexachlorobenzene	0.5	0.25	10.0
Vinyl Chloride	0.25	0.25	1.0

Table 3: Calculated individual risk, summed risk, additive risk, and total risk for each individual chemical and each route of exposure.

CHEMICALS	ROE 1 (mg/kg)	ROE 2 (mg/kg)	ROE 3 (mg/kg)	SUMMED RISK
Benzene	3.0×10^{-6}	4.0×10^{-6}	5.0×10^{-7}	*7.5×10^{-6}*
TCE	5.0×10^{-7}	7.5×10^{-7}	2.0×10^{-7}	*1.45×10^{-6}*
Hexachlorobenzene	5.0×10^{-7}	2.0×10^{-6}	5.0×10^{-8}	*2.55×10^{-6}*
Vinyl Chloride	1.0×10^{-6}	1.0×10^{-6}	5.0×10^{-6}	*7.0×10^{-6}*
ADDED RISK	*5.0×10^{-6}*	*7.75×10^{-6}*	*5.75×10^{-6}*	***1.85×10^{-5}***

As an example, the risk for benzene for ROE 1 is calculated as follows:

$$R = \frac{RL \times C}{T} = \frac{(1 \times 10^{-6}) \times 1.5}{0.5} = 3.0 \times 10^{-6}$$

Note the above evaluation has to be performed for each receptor. In this example the cumulative risk at the site is 1.85×10^{-5} which is above the cumulative target risk of 1.0×10^{-5}. Therefore, further evaluation (remediation or Tier 2) would be required at this site.

If remediation is the preferred option then the estimated risk can be reduced to the target risk using several different alternatives, each of which will result in different clean up levels. Thus there will not be a unique set of target levels. Three examples are given below.

Example 1

The risk of each of the chemicals may be reduced by a factor of 1.85 so that the cumulative risk is reduced to 1.0×10^{-5}, resulting in the following clean up levels:

CHEMICALS	ROE 1 (mg/kg)	ROE 2 (mg/kg)	ROE 3 (mg/kg)
Benzene	0.81	0.54	1.08
TCE	0.27	0.41	0.54
Hexachlorobenzene	0.14	0.27	0.27
Vinyl Chloride	0.14	0.14	2.7

Example 2

Institutional controls may be used to eliminate two of the pathways, thereby eliminating the associated risk, for example:

CHEMICALS	ROE 1 (mg/kg)	ROE 2 (mg/kg)	ROE 3 (mg/kg)	SUMMED RISK
Benzene	ELIMINATED PATHWAY	$4.0 \text{ x } 10^{-6}$	ELIMINATED PATHWAY	*$4.0 \text{ x } 10^{-6}$*
TCE		$7.5 \text{ x } 10^{-7}$		*$7.5 \text{ x } 10^{-7}$*
Hexachlorobenzene		$2.0 \text{ x } 10^{-6}$		*$2.0 \text{ x } 10^{-6}$*
Vinyl Chloride		$1.0 \text{ x } 10^{-6}$		*$1.0 \text{ x } 10^{-6}$*
ADDED RISK		*$7.75 \text{ x } 10^{-6}$*		***$7.75 \text{ x } 10^{-6}$***

This means that the estimated risk at the site is simply the risk from the remaining complete pathway.

Example 3

In this case the concentrations of the chemicals are reduced. For example we could reduce the concentrations of benzene and vinyl chloride by one half, and reduce concentrations of TCE and hexachlorobenzene by three-quarters.

CHEMICALS	ROE 1 (mg/kg)	ROE 2 (mg/kg)	ROE 3 (mg/kg)	SUMMED RISK
Benzene	$1.5 \text{ x } 10^{-6}$	$2.0 \text{ x } 10^{-6}$	$2.5 \text{ x } 10^{-7}$	*$3.75 \text{ x } 10^{-6}$*
TCE	$1.25 \text{ x } 10^{-7}$	$1.875 \text{ x } 10^{-7}$	$5.0 \text{ x } 10^{-8}$	*$3.63 \text{ x } 10^{-7}$*
Hexachlorobenzene	$1.25 \text{ x } 10^{-7}$	$5.0 \text{ x } 10^{-7}$	$1.25 \text{ x } 10^{-8}$	*$6.37 \text{ x } 10^{-7}$*
Vinyl Chloride	$5.0 \text{ x } 10^{-7}$	$5.0 \text{ x } 10^{-7}$	$2.5 \text{ x } 10^{-6}$	*$3.5 \text{ x } 10^{-6}$*
ADDED RISK	*$2.25 \text{ x } 10^{-6}$*	*$3.18 \text{ x } 10^{-6}$*	*$2.81 \text{ x } 10^{-6}$*	***$8.25 \text{ x } 10^{-6}$***

For this case the cumulative risk at the site is equal to $8.25 \text{ x } 10^{-6}$ and below the target risk.

APPENDIX C
MATHEMATICAL MODELS

Memorandum

Date: November 4, 2002

To: Groundwater Remediation Rule Workgroup

From: Mathematical Models Subgroup

Subject: **Subgroup Final Report**

Models Selected

The Mathematical Models Subgroup met by conference call on two occasions (October 9 and October 18) and in person on September 26 and October 25 prior to the large group meetings. The focus of these meetings was to discuss and agree upon the models to be used for a variety of routes of exposure. This discussion was based upon a sampling of what 18other states use for these pathways (prepared by Atul) and the experiences of various Subgroup members. The following models were agreed upon by the Subgroup for the various routes of exposure.

Outdoor Inhalation from Surface Soil
Emission – Jury
Dispersion – Open Box

Outdoor Inhalation from Subsurface Soil/GW
Emission – NA
Dispersion – NA

Indoor Inhalation from Subsurface Soil
Emission – Johnson & Ettinger (with acknowledgement of model limitations)
Dispersion – Closed Box

Indoor Inhalation from Groundwater
Emission –Johnson & Ettinger (with acknowledgement of model limitations)
Dispersion – Closed Box

Unsaturated Zone Transport
SESOIL – The subgroup agreed on the use of various dilution/attenuation factors (DAF) within the SESOIL model based on the distance from the bottom of the source to the groundwater. For distances of less than 20 feet, the DAF=1, for distances of 20-50 feet, the DAF= 2, and for distances of greater than 50 feet, the DAF=4.

Mixing Zone (groundwater, not surface water)
Summers

Horizontal Migration
Domenicos

Surface Water
NA

The Johnson & Ettinger model has been the subject of some discussion in the environmental community for the last few years, with the criticism being that the model is overly conservative under certain conditions. While the Subgroup recognizes these limitations, they feel that this model is still the best option for the screening-level evaluation of the Indoor Inhalation pathways.

Exposure Factors and Fate and Transport Parameters

The workgroup did not attempt to select and recommend specific factors and parameters to be used in the various equations. It was felt that this effort would be beyond the scope of the group's charge and abilities given the time constraints. Attached is a compilation of nineteen states' default values for exposure and fate and transport, including Missouri's. For the purposes of "test driving," the group recommends using the current Missouri values taken from the CALM document as a baseline recommendation. In the course of the test drive, other baseline factors may be considered, proposed and discussed. At some point, the larger group or another small group may be appointed to resolve issues of whether one or another particular value is more appropriate.

APPENDIX D
GROUNDWATER CLASSIFICATION

Groundwater Classification Subgroup
Work Product

Introduction

The core objective of the subgroup is to develop a process that establishes which groundwaters merit protection as current or future sources of drinking water (i.e. water used for domestic consumption). The subgroup decided that the most appropriate way of making this determination was a site-specific analysis of the groundwater use (domestic consumption) exposure pathway, consistent with the previously proposed risk-based decision-making framework.

In prior stakeholder group discussions, a "groundwater classification" scheme was discussed as the mechanism for characterizing the potential for future use of groundwaters, and making associated risk management decisions (POE concentrations, POE location, etc.) The subgroup concluded that the groundwater classification scheme previously discussed was problematic. For example, there were concerns that the classification combined too many deliberations into a single step. In addition, the subgroup found that the degree of prescriptiveness in such a classification approach necessitated a corresponding degree of specificity in classification criteria that would be inherently controversial. The subgroup concluded that the inherent controversy outweighed any incremental benefits of the classification over and above the exposure pathway analysis approach.

Exposure Pathway Analysis for Domestic Consumption of Groundwater

In the proposed risk-based decision-making (RBDM) framework, a key objective of the Site Conceptual Model is to define the exposure pathways that are complete under current conditions or reasonably anticipated future use. Complete exposure pathways are carried forward for additional evaluation in the risk management process. For the domestic consumption of groundwater exposure pathway, one must determine if the groundwater is currently being used for domestic consumption, or if there is a reasonable probability that the groundwater will be used as a source of domestic water supply in the future. This section outlines the process to be used in making this determination.

Overview of Process

Together, the "identify existing wells" step and "reasonable probability of site impact" determination constitute the assessment of the groundwater use pathway under current conditions. If existing wells could be impacted by site conditions, the pathway is considered complete, and is carried forward for further analysis or management in the RBDM process.

The analysis of the "future groundwater use" exposure pathway starts with the "identify groundwater zones" step. Each applicable groundwater zone goes through the "suitable for use", "only source", "reasonable probability of future use" and "reasonable probability of site impact" determinations. If groundwater zones with a reasonable probability of serving as future sources of domestic water supply could be impacted by site conditions, the pathway is considered complete, and is carried forward for further analysis or management in the RBDM process.

Site-Specific Data Collection

The analysis of the domestic use groundwater pathway is a site-specific analysis that must be based on data. Required data will typically include regional hydrogeologic information, water well and groundwater use survey data, and site-specific information on site hydrogeology and the nature and extent of groundwater impacts. The type and amount of data required for a specific site will vary based on a number of site-specific factors including the complexity of the site and the specific determinations that ultimately drive the outcome of the exposure pathway analysis. The goal of data should be to obtain data of sufficient quantity and quality to support RBDM decisions, in the most cost-effective manner, taking into consideration the relative potential risks posed by the site.[1]

Identify Existing Wells

Existing wells on or in the vicinity of the site must be identified. At a minimum, the State of Missouri's well data base should be searched.[2] While this will not provide a comprehensive listing of all wells in the vicinity, it provides a valid indicator of the degree to which groundwater in the vicinity is being used. Depending on the results of the search and other known facts about the site, more intensive well survey techniques may be warranted. A more intensive well survey should generally be conducted throughout the current and projected extent of the groundwater plume.

The presence of springs must be evaluated pursuant to the "groundwater use" and/or "groundwater discharge to surface water" components of the site conceptual model. If the springs are used or could be used as a source of domestic water supply prior to discharge to and mixing in the receiving surface water, it will generally be most appropriate to evaluate the springs pursuant to the groundwater use framework. Groundwater discharge to springs may also need to be evaluated pursuant to the "groundwater discharge to surface water" framework (e.g. to evaluate discharge of springs to surface waters that are subsequently used as a source of water supply).

Identify Groundwater Zones

All groundwater zones beneath and/or in the vicinity of the site that could potentially be targeted in future water well installation should be identified. For the purposes of this analysis, the saturated zone can be divided into multiple "layers", but all layers within the saturated zone (and particularly zones in hydraulic communication with the impacted zone) must be considered.[3]

Sufficient Institutional Control Determination

If there is an institutional control that essentially eliminates any reasonable probability that the groundwater zone under considerations will ever serve as a future source of domestic water supply, no further evaluation of the groundwater use (domestic consumption) pathway is required for that groundwater zone.[4]

Suitability for Use Determination

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[1] For example, the installation of 200-foot deep wells will generally not be required to evaluate the hydrogeology of a site if regional hydrogeologic data is available.

[2] The search should include the WIMS data base of certified wells, and should also include the LOGMAIN data base of well logs as appropriate.

[3] For example, an applicant may elect to identify the low-permeability soils that comprise the upper 50 feet of the saturated zone as a separate zone from more permeable strata immediately underlying the low-permeability strata. However, both zones would have to be identified and considered in the analysis.

[4] The attributes of an institutional control that are sufficient to "essentially eliminate any reasonable probability" need to be defined by the institutional control group. It was the thinking of the groundwater classification subgroup that one of these attributes should be the specific targeting of the groundwater zone by the institutional control (i.e. the entity implementing the institutional control should explicitly define the groundwater zone or zones that they have decided to eliminate as potential sources of future water supply).

For groundwater to be considered a viable water supply source, two major criteria must be met. First, the groundwater must be of usable quality, and second, the aquifer must be capable of producing a usable quantity of water.

Groundwater containing less than 10,000 mg/L total dissolved solids shall be considered as having sufficient natural quality to serve as a potential source of domestic water supply.[5]

Groundwater zones capable of producing a minimum of 1/4 gallon per minute or 360 gallons per day on a sustained basis shall be considered as having sufficient yield to serve as a potential source of domestic water supply. The yield of a bedrock aquifer should be based on the measured or calculated production of a 6-inch drilled well that penetrates the lesser of either the full saturated thickness of the aquifer or the uppermost 200 feet of the saturated zone. The yield of a low yield unconsolidated (glacial drift or alluvial) aquifer should be based on the measured or calculated production of a 3-ft diameter augered or bored well that penetrates the lesser of either the entire saturated thickness of the aquifer or the uppermost 50 feet of the saturated zone.[6,7]

Groundwater zones meeting both the TDS <u>and</u> yield criteria will be considered to constitute a suitable source of domestic water supply, and those zones will be carried forward to the "reasonable probability of use" determination.

Sole Source Determination

Regardless of TDS and yield, a groundwater zone shall be carried forward to the "reasonable probability of use" determination if the zone is the only viable source of water supply in the vicinity of the site.

Probability of Future Use Determination

The probability that a groundwater zone could be used as a future source of water supply for domestic consumptions shall be evaluated. The evaluation shall be based on consideration of all factors impacting such probability, including the following:

- Current groundwater use patterns in the vicinity
- Availability of alternative water supplies (including other groundwater zones, municipal water supply systems, and surface water sources)
- Institutional controls.
- Urban development considerations for sites in areas of intensive historic industrial/commercial activity, located within metropolitan areas that had a population of at least 70,000 in 1970, and for groundwater zones in hydraulic communication with such industrial/commercial surface activity.
- Aquifer capacity limitations (ability to support a given production well density)

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[5] This TDS value was acceptable to the subgroup under the assumption that the "suitability of use" determination was only a screen, and that groundwater zones meeting the TDS and yield criterion did NOT equate to zones having a reasonable probability of being future sources of water supply (and having risk-based target levels corresponding to drinking water quality or othersie meriting protection as a potential source of drinking water).
[6] The acceptability of this proposed criterion to the subgroup is based on the assumption that Jim Vandike (or someone) will be able to develop an equation from which the yield can be calculated from a hydraulic conductivity value determined from traditional site investigation techniques. Jim indicated that such a tool should be feasible to develop. ***[Loose end: such a tool will have to be developed at some point.]***
[7] The level-of-effort expended on the yield question should be minimized on zones which would clearly meet the yield criteria. Specifically, there is no need to install a 3-ft. diameter well, or to calculate the yield in such as well, in high yield zones.

Conclusions regarding the probability that a groundwater zone could be used as a future source of domestic water supply shall be based on the weight of evidence. The weight that a single factor will be given in the evaluation will vary based on site-specific considerations. In determining the weight that institutional controls are given in the evaluation, the durability of the institutional control shall be considered.

The weight that institutional controls will play in the determination will depend on the attributes of the specific institutional control. If the institutional control does not have appropriate attributes, the groundwater zone may still be deemed to have a reasonable probability of serving as a future source of domestic water supply, despite the institutional control. If the institutional control does not explicitly apply to a specific water bearing zone that meets each of the following criteria, that groundwater zone will generally be determined as having a reasonable probability of future groundwater use: [8,9]

1. The zone is the highest quality groundwater resource (considering both yield and natural quality) in the hydrostratigraphic column.
2. The zone has sufficient quantity and yield to serve as a primary component of the regional water supply
3. The zone has no widespread groundwater impacts associated with historic human activity in the vicinity of the site (groundwater impacts associated with the specific site are excluded from consideration of this criterion).

The above is only one set of circumstances that would result in a determination that the groundwater zone has a reasonable probability of future use as a domestic water supply.

Each groundwater zone that has a reasonable probability of future use as a domestic water supply shall be carried forward to the "probability of impact" determination.[10]

Probability of Impact Determination

The probability that the site could impact the water quality in an existing well or groundwater zone having a reasonable probability of future use (domestic water supply) shall be evaluated. The evaluation shall consider the nature and extent of contamination at the site, site hydrogeology including the potential presence of karst features, contaminant fate and transport, and other pertinent factors. For the purposes of evaluating potential site impacts on groundwater zones that could serve as future sources of water supply, the potential impact shall be evaluated at the nearest down-gradient location that could reasonably be

[8] This provision was included specifically to address a situation such as in the City of St. Louis, where the deep groundwater (but not the alluvial or shallow bedrock groundwater) could potentially be a significant source of future water supply, despite the presence of the long-standing City Ordnance which prohibits groundwater wells for drinking water supply (which was reportedly implemented due to the cholera epidemic and concerns over the quality of the shallow groundwater).

[9] Note by Piontek (not reviewed or approved by other members of the groundwater classification subgroup): In the subgroup process, I agreed to this provision under the assumption that it would not significantly add to the scope of work of required site investigations or the uncertainty facing developers on Brownfield projects. If this provision does prove a significant hurdle to redevelopment of Brownfield projects, one of the fundamental objectives of the risk-based groundwater remediation rule will not be achieved. If additional input from the redevelopment community indicates this provision will pose a significant hurdle, this provision needs to be revisited, in my opinion.

[10] The subgroup thought it would be most efficacious to leave this determination to a site-specific judgment. However, to provide guidance in this determination, the subgroup recommends: 1) release of case studies that document the intent of the provision, and 2) performance of strategically-selected projects soon after promulgation of the regulation, with involvement of senior DNR staff, to establish firm precedent.

considered for installation of a groundwater supply well. In the absence of durable institutional or engineering controls, the nearest location may be on site.

Consequences of Analysis

If there is a reasonable probability that the site could impact groundwater quality in an existing well or in a groundwater zone having a reasonable probability of future use, the groundwater use (domestic water supply) exposure pathway shall be carried forward in the RBDM process.

Specifically, the pathway will be carried forward for further consideration into Step 5, where representative concentrations of constituents of concern in site groundwater are compared to default risk-based target levels (TL-1) for the groundwater use (domestic consumption) pathway.

If concentrations exceed TL-1 for the groundwater use pathway, the applicant has the option of implementing Step 6 (development of and comparison to site-specific target levels) and either demonstrating attainment of TL-2 concentrations or proceeding to Step 7 (development and implementation of a Risk Management Plan). The latter step will require the identification of a Point of Exposure (POE) for each pathway carried forward. The POE shall be the nearest down-gradient three-dimensional location that could reasonably be considered for installation of a groundwater supply well. If representative onsite groundwater concentrations could cause an exceedance of TL-2 concentrations at the POE, then a Risk Management Plan will be required to address the appropriate groundwater use pathway or pathways.[11]

Associated Policy Choices

Notification of Groundwater Impacts

If contamination above unrestricted use levels (i.e. residential) remains in place, some type of instrument should be implemented to alert subsequent property users (e.g. well drillers who may encounter and have to case through a zone of impact) of the contamination.[12]

Institutional Controls

If the “implementability” of an institutional control that limits groundwater use can be satisfactorily addressed, the group agreed that in some cases putting such an institutional control in place is the easiest and most efficacious path to the desired No Further Action finding (see Case Study 2, the Operating Gas Station). There was agreement that the most significant concern seems to be diminution of property value.

“No Expanding Plume” Requirement

An expanding groundwater plume is generally unacceptable. Thus, one must establish that plumes of impacted groundwater will not migrate beyond the boundaries of currently-impacted properties. To establish this, one must obtain enough site data to demonstrate that the plume is stable or shrinking, or (in the case of a potentially expanding plume) perform groundwater modeling that establishes it is unlikely

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[11] This paragraph cannot be finalized until the RBDM framework is finalized, specifically with respect to the step at which the equivalent of ASTM RBCA Tier 2 is incorporated into the analysis.
[12] The specific types of instrument(s), and the specific trigger(s) for implementation of the appropriate instrument, are to be proposed by the institutional control subgroup.

the plume will migrate beyond the boundaries of currently-impacted properties. Projections of plume extent based on modeling should be confirmed with monitoring data as appropriate. [13]

Groundwater Exposure Pathway Analysis for Multi-Property Sites

In a Brownfield Redevelopment scenario, there may be benefit in establishing the fact that the groundwater use (domestic consumption) pathway does not apply, and that MCLs and other drinking water quality criteria would not be applicable cleanup standards, to a group or properties within a redevelopment zone. The regulation should be structured to allow for such a determination (perhaps through submittal and DNR approval of a Groundwater Use Exposure Pathway Assessment). The "approval" would acknowledge DNR agreement with the findings of the exposure pathway assessment, and that MCLs or drinking water quality criteria would not be applicable cleanup standards for the groundwater use (domestic consumption) pathway, although other pathways would require analysis.[14,15]

Consideration of Risk in Remedy Selection

In the RBDM process, all current or reasonably probable sources of domestic water supply that also have reasonable probability of being impacted by the site (as determined in the groundwater use component of the SCM) will be carried forward for additional evaluation. Some sites may have a very high probability of impacting potential future sources of domestic water supply. Other sites may have a much lower probability, although the probability exceeds the "reasonable probability" test. The Risk Management Plan must specify the combination of passive and active remedial measures necessary to address the exposure pathway. In selecting the appropriate remedy for the site, the relative probability of the groundwater use pathway being complete (incorporating both probability of future use and probability of impact) should be considered, along with other pertinent considerations.

Required Definitions

Domestic Water Use. Use of water to meet residential drinking, bathing, and/or cooking needs.

Others. There are a number of other definitions (POE) that can be taken from Atul's draft process document.

Case Studies

Case studies illustrating the use of the Site Conceptual Model (SCM) decision-making framework described herein are attached.

The groundwater classification subgroup recognizes the criteria imbedded in the proposed process are subjective. The subgroup believes the best way to deal with this subjectivity is through the use of case

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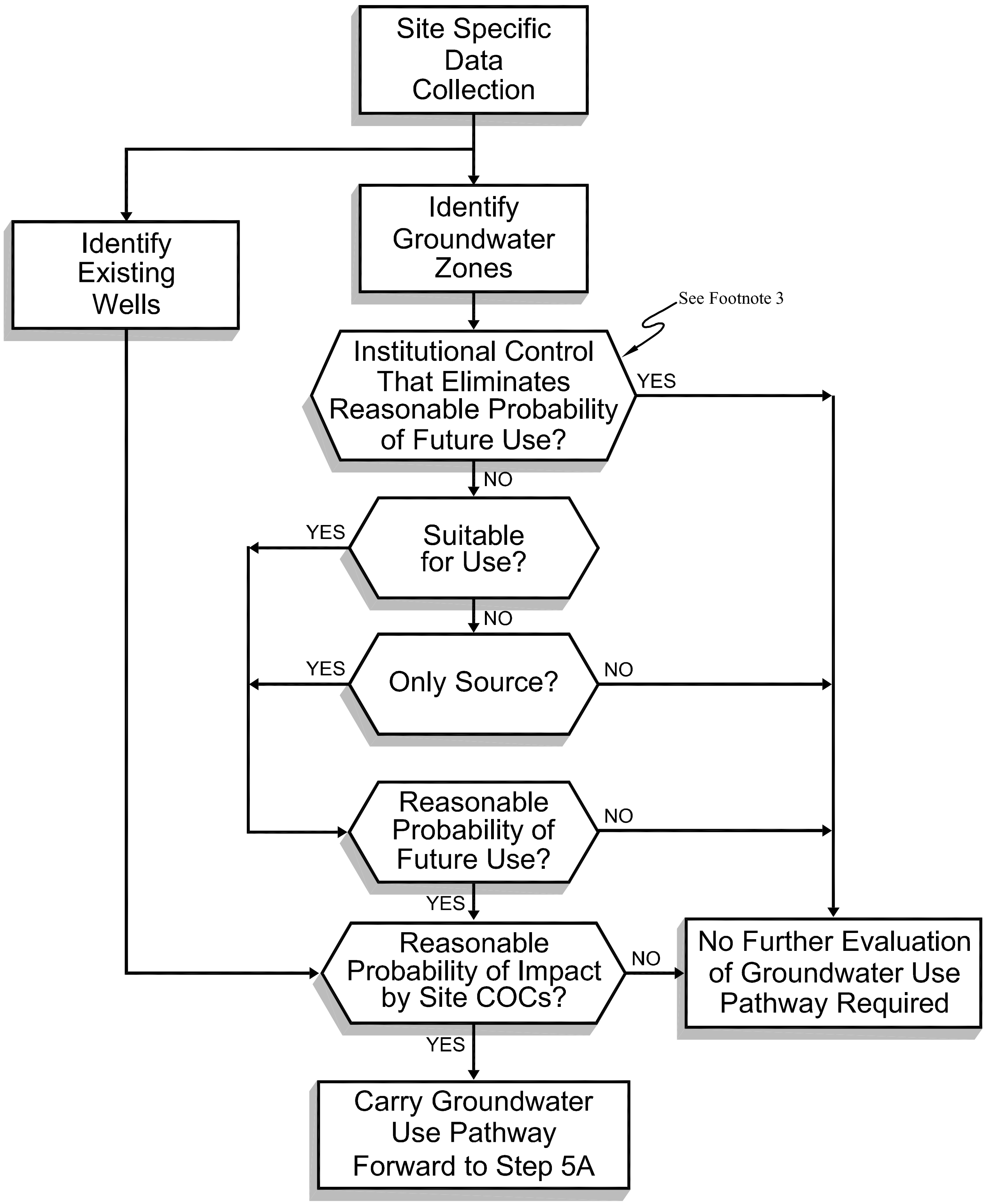
[13] This policy choice is anticipated to apply mainly at sites where there are no risk considerations that would drive plume management (i.e. there are no complete exposure pathways). The subgroup recognized there are disadvantages to making this a universal requirement. For example, this requirement and the associated uncertainty resulting from potential future plume migration would have adverse impacts on Brownfield redevelopment projects. In addition, the subgroup recognized the possibility that the geographical extent of appropriate institutional controls could be a valid consideration in the geographical extent of potential plume migration.

[14] This "approval" would be subject to the usual "re-opener" in the event of additional information on groundwater use being discovered through additional site investigations that would change the findings of the assessment.

[15] There are DNR organizational/staffing issues that have to be resolved (i.e., which staff would do the review and issue a letter?)

studies. These case studies could include the case studies included herein, but should also include at a minimum the results of strategically-selected case studies of actual projects performed soon after promulgation of the regulation, with involvement of senior DNR staff, to establish firm precedent.

STEP 4. Site Conceptual Model
"Domestic Consumption of Groundwater"
Exposure Pathway Analysis



NOTE:

1. In this chart, "use" refers to "domestic consumption".
2. The analysis embodied in the chart is performed for each groundwater zone of interest. The conclusion of the analysis (the groundwater use pathway is either carried forward for additional consideration, or no further evaluation of the pathway is required) applies to the individual groundwater zone under analysis. Different conclusions may apply to different groundwater zones at a given site.
3. The attributes of an institutional control that would be sufficient to "elimiante reasonable probability of future use", and that would be sufficient to conclude "no further evaluation of groundwater use pathway required" at this step in the site conceptual model process, have yet to be defined. It is anticipated that the institutional control subgroup will address this topic.

Case Study 1: Glenstone Gas Station, Springfield

Analysis of Current Groundwater Use

Identify Existing Wells. Well survey identified no wells in immediate vicinity. Of wells in survey, only a few are in the Springfield Aquifer, the rest are deeper. (**Note:** for purposes of the case study, it was assumed that a "door to door" well survey was performed which confirmed that there were no wells in the immediate vicinity (within the potential reach of the plume).

Reasonable Probability of Impact by Site COCs? No - Based on knowledge of aqueous phase BTEX migration potential and distance to wells.

Finding. This pathway not complete (not carried forward for additional analysis).

Analysis of Future Groundwater Use

Identify Groundwater Zones:
Zone 1: Springfield Plateau Aquifer
Zone 2: Ozark Aquifer

Groundwater Zone 1

Institutional Control Sufficient to Eliminate Reasonable Probability of Future Use? This determination is dependent on the outcome of the institutional control policy choices (not available at the time of the case study).

Suitable for Use?
- **Yield:** Adequate
- **Natural quality:** Acceptable

Only Source? Not applicable, "suitability for use" criteria were met.

Reasonable Probability of Future Use?
- **Alternative sources of water supply:** Yes, both municipal supply (mainly surface water) and deeper Ozark (better yield, less likely to be impacted by urban impacts)
- **Institutional controls:** Water Well Driller's Act (state regulation) requires wells to be cased through the Springfield Plateau aquifer, thus prohibiting wells targeting that zone.
- **Urban development considerations:** Very high potential for groundwater impacts associated with urban development, which is presumably the reason for the institutional control. The zone meets the population, land use, and hydraulic communication criteria.
- **Aquifer capacity limitations based on multiple user considerations:** No.

Reasonable Probability of Impact by Site COCs? Not applicable, since the answer to "reasonable probability of site impact" is no.

Finding for Zone 1. The groundwater use pathway (domestic consumption) is not complete at the site. Zone 1 not a probable source of future water supply, based on alternative sources and institutional control.

Groundwater Zone 2

Institutional Control Sufficient to Eliminate Reasonable Probability of Future Use? No.

Suitable for Use?

- **Yield:** Adequate
- **Natural quality:** Acceptable

Only Source? Not applicable, "suitability for use" criteria were met.

Reasonable Probability of Future Use?

- **Alternative sources of water supply:** Yes, municipal supply (mainly surface water). **Institutional controls:** No.
- **Urban development considerations (aka "anthropogenic contamination"):** No, meets population and land use criteria, but not hydraulic communication criterion.
- **Aquifer capacity limitations based on multiple user considerations:** No

Reasonable Probability of Impact by Site COCs? Very low probability, based on depth to Ozark, presence of confining unit, and knowledge of aqueous phase BTEX migration potential.

Finding for Zone 2. The groundwater use pathway (domestic consumption) is not complete at the site (no impact potential).

Case Study 2: Operating Gas Station, St. Louis County (Scenario A)

Analysis of Current Groundwater Use

Identify Existing Wells. There are a couple of wells within 0.5 mile of the site. No on-site well.

Reasonable Probability of Impact by Site COCs? No – There is strong evidence that the plume does not extend off-site, and is shrinking.

Finding. Groundwater is not currently in use.

Analysis of Future Groundwater Use

Identify Groundwater Zones:

Zone 1: Overburden.
Zone 2: Uppermost Bedrock (based on assumption that at least one of the nearby well was recently installed in the uppermost bedrock – further investigation could reveal that is NOT the case).

Groundwater Zone 1

Institutional Control Sufficient to Eliminate Reasonable Probability of Future Use? No.

Suitable for Use?

- **Yield:** Inadequate, does not meet "Vandyke" criteria
- **Natural quality:** N/A

Only Source? No.

Reasonable Probability of Future Use?

- **Alternative sources of water supply:** Yes, municipal supply.
- **Institutional controls:** N/A
- **Urban development considerations:** N/A
- **Aquifer capacity limitations based on multiple user considerations:** N/A

Not a probable source of water supply, based on yield and presence of alternative supply.

Reasonable Probability of Impact by Site COCs? Not applicable, since the answer to 2B is no.

Finding for Zone 1. The groundwater use pathway (domestic consumption) is not complete at the site.

Groundwater Zone 2

Institutional Control Sufficient to Eliminate Reasonable Probability of Future Use? No.

Suitable for Use?

- **Yield:** Adequate
- **Natural quality:** Acceptable

Only Source? Not applicable, "suitability for use" criteria were met.

Reasonable Probability of Future Use?

- **Alternative sources of water supply:** Yes, municipal supply.

- **Institutional controls:** No
- **Urban development considerations:** No
- **Aquifer capacity limitations based on multiple user considerations:** Possibly

Zone 2 is an unlikely, but potential source of future water supply (based on assumption that another well was recently installed in the unit).

Reasonable Probability of Impact by Site COCs? Very low – assume that investigation data establishes that deeper interval above the bedrock is clean, and considering knowledge of BTEX migration potential, and evidence of shrinking plume.

Finding for Zone 2*.* The groundwater use pathway (domestic consumption) is not complete at the site (no impact potential).

Case Study 2B: Operating Gas Station, St. Louis County (Scenario B)

Analysis of Current Groundwater Use

Identify Existing Wells. There are a couple of wells within 0.5 mile of the site. No on-site well.

Reasonable Probability of Impact by Site COCs? No – There is strong evidence that the plume does not extend off-site, and is shrinking.

Finding. Groundwater is not currently in use.

Analysis of Future Groundwater Use

Identify Groundwater Zones:

Zone 1: Overburden.

Zone 2: Uppermost Bedrock (based on assumption that nearby well was recently installed in the uppermost bedrock – further investigation could reveal that is NOT the case).

Groundwater Zone 1

Institutional Control Sufficient to Eliminate Reasonable Probability of Future Use? No.

Suitable for Use?
- **Yield:** Inadequate, does not meet “Vandyke” criteria
- **Natural quality:** N/A

Only Source? Not applicable, “suitability for use” criteria were met.

Reasonable Probability of Future Use?
- **Alternative sources of water supply:** Yes, municipal supply.
- **Institutional controls:** N/A
- **Urban development considerations:** N/A
- **Aquifer capacity limitations based on multiple user considerations:** N/A

Not a probable source of water supply, based on yield and presence of alternative supply.

Reasonable Probability of Impact by Site COCs? Not applicable, since the answer to 2B is no.

Finding for Zone 1. The groundwater use pathway (domestic consumption) is not complete at the site.

Groundwater Zone 2

Institutional Control Sufficient to Eliminate Reasonable Probability of Future Use? No.

Suitable for Use?
- **Yield:** Adequate
- **Natural quality:** Acceptable

Only Source? Not applicable, “suitability for use” criteria were met.

Reasonable Probability of Future Use?
- **Alternative sources of water supply:** Yes, municipal supply.
- **Institutional controls:** Yes, restrictive covenant prohibiting well installation.

- **Urban development considerations:** No
- **Aquifer capacity limitations based on multiple user considerations:** Possibly

Zone 2 is not a potential source of future water supply, based on IC and alternative water supply.

Reasonable Probability of Impact by Site COCs? Very low – assume that investigation data establishes that deeper interval above the bedrock is clean, and considering knowledge of BTEX migration potential, and evidence of shrinking plume.

Finding for Zone 2. The groundwater use pathway (domestic consumption) is not complete at the site (not a probable source of water supply).

Case Study 2C: Operating Gas Station, St. Louis County (Scenario C)

Analysis of Current Groundwater Use

Identify Existing Wells. There are a couple of wells within 0.5 mile of the site. . No on-site well.

Reasonable Probability of Impact by Site COCs? No – There is strong evidence that the plume does not extend off-site, and is shrinking.

Finding. Groundwater is not currently in use.

Analysis of Future Groundwater Use

Identify Groundwater Zones:

Zone 1: Overburden.
Zone 2: Uppermost Bedrock (based on assumption that nearby well was recently installed in the uppermost bedrock – further investigation could reveal that is NOT the case).

Groundwater Zone 1

Institutional Control Sufficient to Eliminate Reasonable Probability of Future Use? No.

Suitable for Use?

- **Yield:** Inadequate, does not meet "Vandyke" criteria
- **Natural quality:** N/A

Only Source? Not applicable, "suitability for use" criteria were met.

Reasonable Probability of Future Use?

- **Alternative sources of water supply:** Yes, municipal supply.
- **Institutional controls:** N/A
- **Urban development considerations:** N/A
- **Aquifer capacity limitations based on multiple user considerations:** N/A

Not a probable source of water supply, based on yield and presence of alternative supply.

Reasonable Probability of Impact by Site COCs? Not applicable, since the answer to 2B is no.

Finding for Zone 1. The groundwater use pathway (domestic consumption) is not complete at the site.

Groundwater Zone 2

Institutional Control Sufficient to Eliminate Reasonable Probability of Future Use? No.

Suitable for Use?

- **Yield:** Adequate
- **Natural quality:** Acceptable

Only Source? Not applicable, "suitability for use" criteria were met.

Reasonable Probability of Future Use?

- **Alternative sources of water supply:** Yes, municipal supply.

- **Institutional controls:** No (assume property owner was unwilling to put institutional control in place).
- **Urban development considerations:** No
- **Aquifer capacity limitations based on multiple user considerations:** Possibly

Zone 2 is an unlikely, but potential source of future water supply (based on assumption that another well was recently installed in the unit). Agreement that this finding was "on the edge of reasonable probability."

Reasonable Probability of Impact by Site COCs? Possible (for purposes of this scenario, assume contamination extends to top of bedrock).

Finding for Zone 2. The groundwater use pathway (domestic consumption) is potentially complete. POE is at uppermost bedrock, beneath plume. POE concentrations are drinking water quality criteria. (Piontek argued that low probability of exposure should translate to criteria corresponding to lower end of risk range, but there was general agreement this would be a tough sell with larger group).

Case Study 3: Former Dry Cleaners Site, St. Louis County

Analysis of Current Groundwater Use

Identify Existing Wells. Assume: 1) data base available at DNR GSRAD was reviewed and indicated no wells within two miles, and 2) surrounding developments are commercial, indicating little likelihood of private well use nearby. Therefore, the answer is no.

Reasonable Probability of Impact by Site COCs? N/A, no existing wells..

Finding.

Analysis of Future Groundwater Use

Identify Groundwater Zones:

Zone 1: Silty clay
Zone 2: Mississippian limestone

Groundwater Zone 1

Institutional Control Sufficient to Eliminate Reasonable Probability of Future Use? No.

Suitable for Use?
- **Yield:** Adequate
- **Natural quality:** Adequate

Only Source? Not applicable, “suitability for use” criteria were met.

Reasonable Probability of Future Use?
- **Alternative sources of water supply:** Zone 2 and municipal.
- **Institutional controls:** Not currently, but the owner is willing to accept a restrictive covenant.
- **Urban development considerations:** No, meets population and hydraulic communication criteria, but not land use criterion.
- **Aquifer capacity limitations based on multiple user considerations:** Yes

Reasonable Probability of Impact by Site COCs?

Finding for Zone 1. Due primarily to the availability of higher-quality, deeper water source, as well as other factors, no reasonable probability of use (domestic consumption).

Groundwater Zone 2

Institutional Control Sufficient to Eliminate Reasonable Probability of Future Use? No.

Suitable for Use?
- **Yield:** Adequate, but not great
- **Natural quality:** Adequate, but not great

Only Source? Not applicable, “suitability for use” criteria were met.

Reasonable Probability of Future Use?
- **Alternative sources of water supply:** Yes, municipal.
- **Institutional controls:** No, although the owner is willing to accept a restrictive covenant.
- **Urban development considerations:** No.

- **Aquifer capacity limitations based on multiple user considerations:** Capacity could support low-density use, but insufficient to support high-density use.

Reasonable Probability of Impact by Site COCs? Field data indicates low contamination at bedrock interface, and the likelihood at the bedrock interface is low. Modeling indicated that the plume could reach the property boundary in 75 years, but there is much uncertainty in such modeling.

Finding for Zone 2. Agreed probability of future domestic use is low, no reasonable probability of groundwater use. . Also agreed the threat of impact to Zone 2 is low.

Problem: The subgroup had previously agreed that plume expansion is generally unacceptable, regardless of risk considerations. We do not know whether the plume is stable or shrinking, or with much certainty, whether the plume will ever reach the property boundary. So what do we do? We have 8 quarters of monitoring well data; a sentinel well has shown no impact so far, but 8 quarters over two years in a setting with very low gw velocities is essentially one data point. There was agreement that on this site, the frequency of groundwater monitoring should reflect the very low groundwater velocity, and that a relatively infrequent monitoring program would be appropriate. If one has a well at the edge of the plume, and one collects a sample at 5 yrs, then at 10, one can rerun the model with additional data and get either confirmation of the model, or modify it - i.e. design a sampling program that provides samples over a 5-year or 10-year period, and use that data to refine the model predictions. Three possibilities: Plume is shrinking, stable or expanding. If shrinking, NFA. If stable, NFA. If expanding, then what?…….. What if the rerun of the model shows that the model is right, i.e., the plume may expand to reach the property boundary 65 years later? We couldn't decide…..

Larry Folkins pointed out that the inability to get a NFA sooner than 10 years is enough to kill most developments. We discussed the possibility of a "provisional NFA" being issued now, with the monitoring requirements still being imposed. But we were still left with the problem of not knowing whether the plume is stale or shrinking, and not being able to determine that with any certainty sooner than 10 years from now.

An alternative: Spend $300,000 on HRC now, then check wells in a year, and hopefully the contaminants will have been largely eliminated or reduced below levels of concern. We agreed this may make sense if the development potential of the property makes it worthwhile. But if it is a property of zero value, and it will lie fallow forever because it is not worth a $300,000 investment…… ?

Consensus Acknowledgement: A "prohibition against ongoing plume expansion" (regardless of risk) is a "feel good" thing to do, and it isn't a big problem at many or most sites. However, this is the kind of uncertainty that may be a "deal killer" on redevelopment projects.

Case Study 4: SW MO Main Street Dry Cleaner

Analysis of Current Groundwater Use

Identify Existing Wells. Small town, on the outskirts of town (1/2 mile away) there are private wells in the Springfield Plateau. The town is on a municipal supply that uses Ozark wells.

Reasonable Probability of Impact by Site COCs? A distinct possibility based on presence of DNAPL, and persistence of CVOCs (potential for aqueous phase transport to wells).

Finding. Yes, currently in use.

Analysis of Future Groundwater Use

Identify Groundwater Zones:
Zone 1: Springfield Plateau
Zone 2: Ozark

Groundwater Zone 1

Institutional Control Sufficient to Eliminate Reasonable Probability of Future Use? No.

Suitable for Use?
- **Yield:** Adequate
- **Natural quality:** Acceptable

Only Source? Not applicable, "suitability for use" criteria were met.

Reasonable Probability of Future Use?
- **Alternative sources of water supply:** Yes, Ozark and municipal (also Ozark).
- **Institutional controls:** No, but owner amenable to deed instrument.
- **Urban development considerations:** No
- **Aquifer capacity limitations based on multiple user considerations:** No

Zone 1 is a probable future source of water supply

Reasonable Probability of Impact by Site COCs? High (the plume already extends offsite).

***Finding for Zone 1*.** Risk of contaminating existing wells, the zone warrants protection as a potential source of drinking water, need to establish POE and POC. If the owner can't get neighbor to implement deed instrument, POE is on the owner's property boundary. If a deed instrument is implemented on the neighbor's property, POE on neighbor's down-gradient property boundary.

Groundwater Zone 2

Institutional Control Sufficient to Eliminate Reasonable Probability of Future Use? No.

Suitable for Use?
- **Yield:** Adequate
- **Natural quality:** Acceptable

Only Source? Not applicable, "suitability for use" criteria were met.

Reasonable Probability of Future Use?
- **Alternative sources of water supply:** No

- **Institutional controls:** No, but owner amenable to deed instrument
- **Urban development considerations:** No
- **Aquifer capacity limitations based on multiple user considerations:** No

Zone 2 is a probable source of future water supply

Reasonable Probability of Impact by Site COCs? Strong indication of DNAPL in the Springfield Plateau aquifer. Good possibility of pre-1930 era wells, mostly in Springfield Plateau. Can't discount the possibility of one through the confining layer. The Ozark Confining Unit is leaky, downward gradient. Reasonable probability of impact if you have old wells into the Ozark, or if you are along the Chesapeake fault. Low probability of detectable impact in the absence of these "hydraulic connection features"

Finding for Zone 2. Zone 2 is a reasonably probable source of future water supply meriting protection. Practically, we would want confirmation of no impact and implementation of measures to reduce the probability of future impact, to the extent practicable. With deed instrument in place, POE in Ozark at property boundary.

Case Study 5: St. Louis City, Alluvial Site
Variety of contaminants; appears to be no migration into deeper bedrock; contaminants appear to be limited to shallow bedrock. Decent gw yield an quality in the alluvium. Groundwater in shallow bedrock is of ample quality and yield to meet criteria we have discussed; (10-15 gpm in shallow zone; 50-465 gpm in deeper zone.)

Analysis of Current Groundwater Use
No drinking water supplies within one mile of site; St. Louis ordinance prevents gw wells. Nearest downstream water intake in river is 68 miles downstream. No indication of domestic use of wells in the vicinity.

Identify Existing Wells. No public or private wells in the immediate vicinity.

Reasonable Probability of Impact by Site COCs? No. Contaminant is primarily onsite; only offsite impact is toward river, where there are no wells.

Finding. The “current groundwater use” pathway is not complete.

Analysis of Future Groundwater Use

Identify Groundwater Zones:
- **Zone 1:** Alluvium
- **Zone 2:** Shallow bedrock (Pennsylvanian)
- **Zone 3:** Deeper bedrock

Groundwater Zone 1 - Alluvium

Institutional Control Sufficient to Eliminate Reasonable Probability of Future Use? The IC has been in place 118 years, and was implemented specifically to address contamination of this zone. This determination is dependent on the outcome of the institutional control policy choices (not available at the time of the case study).

Suitable for Use?
- **Yield:** Adequate
- **Natural quality:** Adequate

Only Source? Not applicable, “suitability for use” criteria were met.

Reasonable Probability of Future Use?
- **Alternative sources of water supply:** Yes
- **Institutional controls:** Yes, City of St. Louis Ordinanace. Sturgess noted the St. Louis ordinance has been on the books for 118 years, giving some assurance of durability. The property owner has limitations in place which would also limit use of water onsite.
- **Urban development considerations:** Yes, based on considerations including extensive fill at the site and ancient sewer system.
- **Aquifer capacity limitations based on multiple user considerations:** No

Reasonable Probability of Impact by Site COCs? We know this zone is impacted.

Finding for Zone 1. Considering all factors, is very unlikely the water will ever be used for a domestic water source. Zone 1 does not have a reasonable probability of being used as a future source of water supply for domestic consumption.

Groundwater Zone 2 – Shallow Bedrock

Institutional Control Sufficient to Eliminate Reasonable Probability of Future Use?
Discuss. The IC has been in place 118 years, and was implemented specifically to address contamination of this zone.

Suitable for Use?
- **Yield:** Adequate
- **Natural quality:** Adequate

Only Source? Not applicable, “suitability for use” criteria were met.

Reasonable Probability of Future Use?
- **Alternative sources of water supply:** Yes
- **Institutional controls:** Yes, see above.*
- **Urban development considerations:** Yes
- **Aquifer capacity limitations based on multiple user considerations:** Yes

Reasonable Probability of Impact by Site COCs? Probable

Finding for Zone 2. Considering all factors, is less likely to be used as a domestic water source; probably less likely than the alluvium. Zone 2 does not have a reasonable probability of being used as a future source of water supply for domestic consumption.

Groundwater Zone 3 – Deeper Bedrock

Institutional Control Sufficient to Eliminate Reasonable Probability of Future Use?
Discuss. The IC has been in place 118 years, but this deeper zone was not a practical source of water supply at the time the IC was implemented. Was the IC intended to apply to this zone? Nonetheless, actual use of this zone (domestic water supply) does not occur, due at least in part to the IC.

Suitable for Use?
- **Yield:** Yes
- **Natural quality:** Yes

Only Source? Not applicable, “suitability for use” criteria were met.

Reasonable Probability of Future Use?
- **Alternative sources of water supply:** Yes, municipal water supply
- **Institutional controls:** Yes, St. Louis City Ordinance.
- **Urban development considerations:** No. Meets population and land use considerations, but not hydraulic connection criterion.
- **Aquifer capacity limitations based on multiple user considerations:** No

Reasonable Probability of Impact by Site COCs? Willing to conclude there is low probability, based on what is known about the levels and location of the contaminants. (Assumed no DNAPLs, but even if there is, the site is entirely paved, there is no ongoing source, and the shallow bedrock would likely retard the migration to deeper bedrock.)

Finding for Zone 3. Not very likely to be used as a domestic water source, but more likely than other two zones. Based on the assumption that this zone had the quality, quantity, and yield such that it could potentially one day constitute an important component of the regional water supply, it was agreed that this zone should be classified as having a reasonable probability of being used as a future source of water supply. In this case, there is not a reasonable probability that the zone could be impacted by the site contamination. If there was such a probability, the zone would be carried forward in the process (e.g. probably meriting a risk management plan at a later step in the process).

Case Study 6: Alluvial Site in North KC
On Armour Rd in NKC; old pesticide/herbicide formulating facility. COCs include arsenic, 2,4-D, PCP and sodium chlorate. Arsenic levels in soil are very high. Plume boundary map not available, but gw contamination is known to extend about 2000 ft offsite.

Analysis of Current Groundwater Use

Identify Existing Wells. Unlikely there are any domestic use wells in the immediate vicinity. City has 5 alluvial water supply wells located 1.3 miles downgradient from the site; they are not impacted. However, an industrial well approx ¼ mile away in the alluvium was impacted.

Reasonable Probability of Impact by Site COCs? Based on knowledge that an industrial well 1/4 mile away has been impacted, and the fact that there are municipal wells within one mile, and in the absence of proof to the contrary, one could conclude yes. However, Sturgess noted one could collect additional field data and do modeling to better evaluate this. USGS has done that very thing, and demonstrated that even in 100 years under a low river flow, high pumping scenario, the municipal wells would not be impacted. This being the case, answer this question no.

Finding. Based on "no reasonable probability of impact", "current groundwater use" pathway is incomplete.

Analysis of Future Groundwater Use

Identify Groundwater Zones:
Zone 1: Alluvium
Zone 2: N/A

Groundwater Zone 1 - Alluvium

Institutional Control Sufficient to Eliminate Reasonable Probability of Future Use? No.

Suitable for Use?
- **Yield:** Yes
- **Natural quality:** Yes

Only Source? Not applicable, "suitability for use" criteria were met.

Reasonable Probability of Future Use?
- **Alternative sources of water supply:** Yes, surface water, municipal supply.
- **Institutional controls:** No
- **Urban development considerations:** No. Meets population and hydraulic communication criteria, but not land use criterion.
- **Aquifer capacity limitations based on multiple user considerations:** No

Reasonable Probability of Impact by Site COCs? Plume migration is to the southwest.

Finding for Zone 1**.** Referring to Piontek's flowchart, first must reach a conclusion as to whether there is a reasonable probability of future use. Agreed yes. Then, is there a reasonable probability of impact? Yes, because the contamination has already impacted other properties. Therefore, the groundwater ingestion pathway must be carried forward for further analysis, and the owner must design a risk management plan that either accomplishes cleanup of offsite properties and eliminates this future pathway for his property, or clean it all up!

APPENDIX E
INSTITUTIONAL CONTROLS

MASTER COMMENT DRAFT

Institutional Controls Sub Group

Proposed Activity And Use Limitation Regulation

Revised April 7, 2003

I. Purpose: Activity and Use Limitations (AULs), when utilized, are an integral part of a risk management plan designed to ensure that pathways of exposure to contaminants of concern, through current or reasonable future uses, are not completed for as long as such contaminants pose an unacceptable risk to human health and the environment. To achieve this goal, AULs must be durable, reliable, enforceable, and consistent with the risk posed by the contaminants of concern. Without compromising their protective function, AULs are also intended to facilitate the property transaction**,** redevelopment and beneficial reuse of brownfields and other contaminated properties.

II. AUL Definition: Activity and Use Limitations are legal or physical restrictions or limitations on the use of, or access to, a site or facility to eliminate or minimize potential exposures to contaminants of concern, or to prevent activities that could interfere with the effectiveness of a response action, to ensure maintenance of a condition of “acceptable risk” or “no significant risk” to human health and the environment.. (ASTM E2091).

III. Applicability: AULs shall apply whenever Risk Management Plan levels of contaminants exceed unrestricted use levels.[1]

IV. Presumptive AULs for Tank and Petroleum Sites: [The content of this section is to be determined, pending discussions between MDNR and representatives of the petroleum industry and the PSTIF, and pending the outcome of the Pilot Site test applications of the current working draft version of the cleanup rule. MDNR, PSTIF and petroleum industry representatives will work together to develop presumptive AULs that apply to most tank and petroleum sites and that provide a predictable and cost-effective AUL solution that is also fully protective of human health and the environment, per letter of Mr. Werner, 1/23/03][2]

V. Consequences of Breach: State may require additional response action, or may take other enforcement action, pursuant to applicable federal and state laws and regulations (for RCRA, CERCLA, Federal Facilities, etc.), agreements with owner that

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[1] To the extent the risk management plan finds that certain contaminants of concern in excess of unrestricted use levels are not subject to any complete or potentially complete exposure pathway, now or in the future, as determined by the site conceptual model, such findings may serve as an AUL with respect to those contaminants of concern provided the risk management plan is properly documented, entered into an information system, and publicly accessible in accordance with Department requirements.

[2] Presumptive AULs may be developed for other categories of sites with common issues, fact patterns and solutions to AUL needs. Additional presumptive AUL categories may include dry cleaner sites and others.

run with land, financial assurances (if required), or insurance mechanisms as created by Department.

VI. Menu of Tools; Layering: Any of the following tools may be used, and multiple tools may be layered as needed, to serve as the AUL for a specific site.

1. **Deed Notice.**

   (a) A deed notice (as provided by applicable State or Federal laws or regulation) may function as an AUL.

   (b) Deed Notices must be submitted to the recorder of deeds for the county in which the site is located within 60 days of submittal of the final assessment report or as otherwise agreed to in writing by the department. A notice shall be filed under this subsection only by the property owner or with the express written permission of the property owner. The content of the notice is subject to the approval of the Department, but shall at a minimum include:

   - **i.** the Certificate of Completion or equivalent instrument issued by the Department
   - **ii.** A brief description of the area of extent of residual contaminants of concern, and instructions on how to access records, archives, databases, or other information systems where complete site characterization and risk management plan documents are available for review. The description may consist of a legal description for on-site contamination or a survey, and a survey of off-site contaminated areas.;
   - **iii.** A summary of the land use restrictions, if any, required by the risk management plan.
   - **iv.** A statement of what assumptions regarding land use were used as the basis of the risk management plan and response action.
   - **v.** Evidence of recording.

   (c) Any proposed future use of the land for residential (unrestricted) purposes, or which creates a complete or potentially complete exposure pathway, or deviates from the exposure assumptions in the risk management plan, requires prior notice to the Department and may necessitate further evaluation of potential risks to human health and the environment.

2. **Certificates of Completion/NFA Letters.** Certificates of Completion, No Further Action Letters, or other equivalent official determinations that remedial objectives have been attained, and which are subject to revocation for non-compliance with any terms of such determination;

3. **Restrictive Covenant**

   (a) The restrictive covenant shall be submitted to the recorder of deeds for the county in which the property is located within 60 days from submittal of the final assessment report or as otherwise agreed to in writing by the department.

(b) The restrictive covenant shall be filed only by the property owner or with the express written permission of the property owner.

(c) The restrictions shall run with the land and be binding on the owner's successors, assigns, and lessees.

(d) The restrictions shall apply until the department determines that contaminants of concern no longer present an unacceptable risk to human health or the environment.

(e) The form and content of the restrictive covenant are subject to approval by the Department, and shall include:

- **i.** A survey and property description which define the areas addressed by the risk management plan; and
- **ii.** The scope of any land use or resource use limitations.

(f) The restrictive covenant shall also:

- **i.** Restrict activities at the site that may interfere with the response action, operation and maintenance, monitoring, or other measures necessary to assure the effectiveness and integrity of the response action.
- **ii.** Restrict activities that may result in exposure to, or release of, contaminants of concern above levels established in the risk management plan.
- **iii.** Provide that in the event of a change in ownership of the site, the continued effect of any no further action letter or equivalent determination is contingent upon prior notice and acceptance by the prospective owner of all owner obligations with respect to the risk management plan, response action and AULs.
- **iv.** Grant to the department and its designated representatives the right to enter the property at reasonable times for the purpose of determining and monitoring compliance with the risk management plan, including but not limited to the right to take samples, inspect the operation of the response action measures, and inspect records.
- **vi.** Describe generally the uses of the property that are consistent with the risk management plan.
- **vii.** Provide a specific mechanism to modify or remove the restrictive covenant, subject to written Department approval that the site is suitable for unrestricted use.

4. Easement. (Easements will be approved by the Department on a case by case basis. Guidance will be developed, either new or revised, on the subject of easements for use as an AUL.)

5. **Contract.** (Contracts will be approved by the Department on a case by case basis. Guidance will be developed, either new or revised, on the subject of contracts for use as an AUL.)

6. **Legislation:** An AUL may be based upon a local government ordinance, or a State[3] statute or regulation that prohibits the use of land in a manner and to a degree that protects against unacceptable exposure to a contaminant of concern as defined by the cleanup criteria identified in the risk management plan. In order for an ordinance to serve as an AUL under this subsection, it must include both of the following:

   (a) A requirement that the local unit of government notify the Department in writing 30 days before adopting a modification to the ordinance or the lapsing or revocation of the ordinance.

7. **Financial Responsibility Mechanism.** (Guidance will be developed on the subject of financial responsibility mechanisms for use as an AUL. Such mechanisms may include: escrow accounts, bonds, trusts, insurance policies, or combinations of two or more these devices).

8. **Other Mechanisms:** Any other mechanism approved by the Department which performs the necessary functions and possesses the necessary characteristics of AULs for the requirements of the site. These may include agreements with federal agencies regarding current or formerly used defense facilities and other properties, agreements with Department of Transportation concerning sites underlying highways, utilities, or other structures deemed to be permanent, public infrastructure facilities for the site risk horizon of the contaminants of concern.

[END OF CONFERENCE CALL WITH MDNR]

VII. AUL Process: This Process shall apply to all AULs, except those subject to the subsection for Tanks and Petroleum Sites, above.[4]

1. The AUL shall be incorporated into the risk management plan (RMP). The AUL shall provide the required level of durable and reliable protection for all potential exposure pathways based on reasonable future use, as determined by the site

[3] In keeping with the spirit of a comment made during the conference call that we not overlook federal law and federally regulated facilities, I suggest adding the following here: "**or Federal statute, regulation, permit, order, consent decree or agreement**"

[4] COMMENT: AUL Process should contain provision for modification of use. RP should be able to petition for removal of use restriction if risk is less than thought in RMP. Dept. should be able to restrict additional uses if research finds risk is greater than thought in RMP. [LV]; COMMENT: Allowing new restrictions after an RMP and AUL has been approved and implemented based on new research will severely impact redevelopment. [AB].

conceptual model. Layering of tools in an AUL **is encouraged, but not required, if the requisite durability, reliability and protection can be demonstrated by a single tool.**[5]

2. The proposed RMP including the AUL shall be submitted to the Department for review *prior to implementation*.[6] The RMP shall include a determination of the long-term AUL costs to both the Department and the RP. If the RMP is approved, the Department shall issue a RMP approval letter approving the RMP and stating the intention to declare "No Further Action" will be required upon the completion of the ***response action***[7] and implementation of the AUL. Information about the site and its approved RMP will be entered into a central AUL database maintained by the Department.[8]

3. Upon submittal of *and approval of*[9] an RMP completion report by the RP documenting the completion of ***response action*****s** and implementation and recording of AULs, and notification of all parties required by the RMP/AUL, the Department shall issue a NFA letter. **The NFA letter will be recorded in the county in which the site is located *within 30 days of issuance*[10] and entered into the AUL database.**[11]

III. **Notice:**[12] A person who implements a Risk Management Plan shall provide notice of the land use restrictions that are part of the Risk Management Plan to the local unit of government in which the site is located within 30 days of **submittal**[13] of Risk Management Plan**, unless otherwise approved by the department.**[14]

IV. Monitoring/State AUL Information System[15]

1. **State**[16] **shall *establish and* maintain an information system*, which may incorporate one or more existing information systems,* capable of keeping, tracking, updating and disseminating information about AULs for all sites in the State of Missouri for which AUL tracking is required and shall make the system publicly accessible through web-based utilities. ~~The creation, maintenance and operation of the system will be the responsibility of the Department.~~ The information system *shall* protect the legitimate privacy interests of owners and operators of sites with AULs to the extent**

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[5] REPLACE HIGHLIGHTED TEXT WITH: "may be appropriate but is not required." [BS].
[6] ADDED text in italics, per [JB].
[7] REPLACE "corrective action" WITH '"response action" [BS].
[8] Incorporates grammatical suggestions from CE.
[9] ADDED text in italics, per [JB].
[10] ADDED text in italics, per [JB]. COMMENT: Might want to extend time for recording to at least 60 days. County recorders can vary in timeliness and this should not impact RP's NFA or AUL. [AB].
[11] DELETE LAST SENTENCE. [CE]
[12] REPLACE SECTION TITLE WITH **"Required Notifications"** [CE]
[13] REPLACE "submittal" WITH "approval" [CE]
[14] DELETE ", unless otherwise approved . . . " [CE]
[15] DELETE ENTIRE SECTION [CE]
[16] REPLACE "State" with "MDNR". Comment: Or use "the Department" [AB].

compatible with the system's **purpose of tracking AULs. In no event will the issuance of an RMP approval or a No Further Action certification be delayed by the creation or maintenance of the AUL database.** [17]

2. **The need for monitoring shall be evaluated for all AULs, except that sites subject to the tank and petroleum AUL subsection will be handled separately. If required, the State may perform monitoring or engage appropriate professionals to perform this function. All monitoring information shall be integrated into the AUL information system, as provided above.**
3. **Periodic review evaluation of AUL monitoring shall be undertaken to ensure that it is performing adequately and to recommend changes to AUL monitoring or AUL program.**

NOTE:[18] **If necessary, statutory provisions to redress common law deficiencies for deed notice, restrictive covenants, and other proprietary tools will be enacted to ensure that such tools run with the land and remain in effect on the deed in perpetuity, or until removed or modified in accordance with instrument provisions and Department approval.**

[17] Incorporates several grammatical edits suggested by BS.
[18] DELETE ENTIRE SECTION [CE]

APPENDIX F
NUISANCE CONTROLS

Risk-Based Groundwater Rule Stakeholders Committee, Nuisance Subgroup

Rule Concept:

Nuisance Control

In addition to the evaluation of human health risk and ecological risks, each site should also be evaluated qualitatively for the existence of nuisance conditions including but not limited to objectionable taste or odor in groundwater, aesthetic problems with resurfacing groundwater, and odor from soils remaining in place. This evaluation would be documented and reported.

APPENDIX G
ECOLOGICAL RISK

Definitions:

Commercially or recreationally important species – Commercially important species are species that are not rare, threatened, or endangered that are either harvested for use in commercially available products (or are themselves commercially available products) or are a component of an ecosystem or area that is commercially valuable due to its ability to draw significant numbers of visitors. Examples include trees harvested for timber and other wood products; grasses harvested for forage; and populations of wild fish harvested commercially.

NAPL – Nonaqueous phase liquids. These are typically free product not readily dissolved in water.

Receptor – The ecological entity exposed to the stressor (contaminant). This term may refer to tissues, organisms, populations, communities, and ecosystems. (Guidelines for Ecological Risk Assessment, EPA 1998).

Recreationally important species - Species that are not rare, threatened, or endangered that are either important as game species or as part of an ecosystem or area that is commercially valuable due to its ability to draw significant numbers of visitors. Examples include migratory waterfowl; pheasants and other gamebirds; deer; herons and other wetland avian species; trout, bass and other gamefish; otter; mink; snakes and other reptiles; and frogs and other amphibians.

Waters of the state – All rivers, streams, lakes and other bodies of surface and subsurface water lying within or forming a part of the boundaries of the state which are not entirely confined and located completely upon lands owned, leased or otherwise controlled by a single person or by two or more persons jointly or as tenants in common and includes waters of the United States lying within the state.

Waters of the U.S. – All waters that have been or may be used for foreign or interstate commerce, including their tributaries and adjacent wetlands. All isolated wetlands, waterbodies, intermittent streams, wet meadows and mudflats. Streams are defined by the ordinary high water mark which is the limit line on the shore established by the fluctuation of the water surface. It is shown by such things as a clear line impressed on the bank, shelving, changes in soil character, destruction of terrestrial vegetation, the presence of litter and debris or other features influenced by the surrounding area.

Wetland – Wetlands are defined as those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands are transitional areas between open water and dry land and are often found along bays, lakes, rivers and streams. Some are drier than others and may have standing water or saturated soil conditions only during part of the year. Examples include bottomland forests, swamps, bogs, marshes, wet meadows and seasonal wet woods. (Corps Wetland Delineation Manual, 1987).

Ecological Risk Assessment
Tier 1 Screening Checklist for Potential Receptors and Habitat
Checklist #1

1. Is the site less than (<) ½ mile to a surface water resource (pond, river, lake, etc.)?
2. Are wetlands (e.g., marshes, swamps, fens) on or adjacent to the site?
3. Are contaminated soils uncovered or otherwise accessible to ecological receptors and the elements?
4. Has a process (operational) discharge or storm water permit not been issued for the site?
5. Is the site located in a known Karst environment (see Reference map)?
6. Are there federal or state rare, threatened, or endangered species on or within a ½ mile radius of the site? Note: The ½ mile radius limit does not necessarily apply to situations where a hydrogeological connection exists between the site and karstic features.
7. Are there one or more environmentally sensitive areas (see Ecological Risk Assessment Figure #1 for definition) at or within a ½ mile radius of the site?
8. Are commercially or recreationally important species (fauna or flora) on or within a ½ mile radius of the site?

If the answer is "Yes" to any of the above questions, then complete Ecological Risk Assessment Tier 1 Checklist for Potential Exposure Pathways, Checklist #2.

DRAFT

Ecological Risk Assessment

Tier 1 Checklist of Potential Exposure Pathways

Checklist #2

1.a.) Can contaminants associated with the site leach, dissolve, or otherwise migrate to groundwater?

1.b.) Are contaminants associated with the site mobile in groundwater?

1.c.) Does groundwater from the site discharge to ecological receptor habitat?

Question 1: Could contaminants associated with the site reach ecological receptors via groundwater?

2.a.) Is NAPL present at the site?

2.b.) Is NAPL migrating?

2.c.) Could NAPL discharge occur where ecological receptors are found?

Question 2: Could contaminants from the site reach ecological receptors via migration of nonaqueous phase liquids (NAPL)?

3.a.) Are contaminants present in surface soils?

3.b.) Can contaminants be leached from or be transported by erosion of surface soils?

Question 3: Could contaminants reach ecological receptors via erosional transport of contaminated soils or via precipitation runoff?

4.a.) Are contaminants present in surface soil or on the surface of the ground?

4.b.) Are potential ecological receptors on the site?

Question 4: Could contaminants reach ecological receptors via direct contact?

5.a.) Are contaminants present on the site volatile?

5.b.) Could contaminants on the site be transported in air as dust or particulate matter?

Question 5: Could contaminants reach ecological receptors via inhalation of volatilized contaminants or contaminants adhered to dust in ambient air or in subsurface burrows?

6.a.) Are contaminants present in surface and shallow subsurface soils or on the surface of the ground?

6.b.) Are contaminants found in soil on the site taken up by plants growing on the site?

6.c.) Do potential ecological receptors on or near the site feed on plants (e.g., grasses, shrubs, forbs, trees, etc.) found on the site?

6.d.) Do contaminants found on the site bioaccumulate?

Question 6: Could contaminants reach ecological receptors via ingestion of either soil, plants, animals, or contaminants directly?

7.a.) Are their karstic features (see Ecological Risk Assessment Figure #2 for definition) on or within a ½ mile radius of the site?

7.b.) Is there a hydrogeological connection between the site and karstic features such as seeps, springs, streams or other surface water bodies?

Question 7: Could contaminants reach ecological receptors via transport through a Karst system?
NOTE: If the answer to 7.a., 7.b., or Question 7 is yes, user must seek concurrence from the department's Geological Survey and Resource Assessment Division (GSRAD).

If the answer to one or more of the seven above questions is yes, proceed to Tier 2.

APPENDIX H
REPRESENTATIVE CONCENTRATIONS

Prepared by Risk Assessment & Management Group, Inc.
Modified by Workgroup
11/4/02

RISK BASED CORRECTIVE ACTION

ESTIMATION OF REPRESENTATIVE SOIL AND GROUNDWATER CONCENTREATIONS

Prepared by Risk Assessment & Management Group, Inc.
Modified by Workgroup
11/4/02

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APPENDIX D
ESTIMATION OF REPRESENTATIVE SOIL AND GROUNDWATER CONCENTRATIONS

D.1 BACKGROUND

The site-specific application of the's RBCA process (in the backward mode) results in target levels for each complete pathway identified in the site conceptual exposure scenario (SCES) and each chemical of concern (COC). For site-specific risk management decisions, these target concentrations have to be compared with appropriate representative concentrations. If the RBCA process is performed in the forward mode (option under Tier 2), representative concentrations are necessary to estimate the risk (individual excess lifetime cancer risk for carcinogenic effects or the hazard quotient for non-carcinogenic adverse health effects) for each complete route of exposure (identified in the SCES) and each COC. In this case, site-specific risk management decisions are based on a comparison of the estimated cumulative risk with the regulatory specified target risk. Thus the outcome of a RBCA evaluation critically depends on the representative concentrations.

The calculation of representative concentrations is complicated by several factors. These include (i) spatial variability in the concentrations, (ii) temporal variability in the concentrations, and (iii) lack of sufficient site-specific concentration data. To account for these factors, several methodologies have been used to estimate the representative concentrations. These include (i) maximum, (ii) the upper bound of the 95th percentile one or two sided confidence interval about the mean, (iii) arithmetic average, (iv) area-weighted average, (v) depth-weighted average, (vi) geometric average, and (vii) volumetric average (very rarely used) concentration. Associated with each of these concentrations are certain advantages and disadvantages and there is no uniformly accepted methodology to estimate the representative concentration. Thus the application of a particular methodology to estimate a representative concentration, is ultimately a policy choice. The recommended averaging method can be amended based on site specific conditions. For example on small, simple sites, arithmetic averaging would be as suitable and less cumbersome than using the area-weighted or volume-weighted average. In other more complex conditions, volumetric averaging would be the more appropriate methodology. It is expected that numerically, most sites will tend to be the smaller, simpler sites. To be consistent with the fate and transport models used and assumptions made in the exposure assessment; either volume-weighted or area-weighted average concentration should be used.

Additional complications in the calculation of the representative concentrations arise because the concept of representative concentration is often mistakenly associated with a site as opposed to an exposure pathway. Since there may be several complete pathways at a site, several representative concentrations, one for each complete pathway, have to be estimated. The following sections describe the concept of and the methodology that should be used to estimate the representative concentrations for a Tier 2 evaluation.

The effort necessary to calculate the representative concentrations for certain complete pathways can be avoided in the following three situations:

1. ***If the maximum media-specific concentration does not exceed the target level,***

2. ***If the risk, calculated using the maximum concentration, does not exceed the target risk,***

3. ***If the soil and groundwater concentrations are protective of indoor inhalation, it would not be necessary to evaluate the outdoor inhalation pathway. Thus it would not be necessary to estimate the representative concentration for the outdoor inhalation pathway.***

D.2 CALCULATION OF REPRESENTATIVE CONCENTRATIONS

As mentioned above a representative concentration is necessary for each complete exposure pathway at a site. Based on the pathways typically considered in the RBCA process, the following representative concentrations are necessary for each media:

D.2.1 Surficial Soil (0-3 feet below ground surface)

The RBCA process requires the evaluation of two routes of exposure associated with the surficial soil. These are (i) the ingestion of chemicals in groundwater due to leaching of residual chemicals present in the surficial soil, and (ii) accidental ingestion of soil, outdoor inhalation of vapors and particulate from surficial soil emissions, and dermal contact with surficial soil. These pathways are referred to as the protection of groundwater and the direct contact pathway respectively. Thus at most two different surficial soil representative concentrations are required.

D.2.1.1 Representative surficial soil concentration for the protection of groundwater. Figure D-1 shows the schematic of soil leaching to groundwater. The RBCA process conservatively assumes that the leachate from the surficial soil source travels vertically downwards to the water table without any lateral or transverse spreading. Thus the horizontal dimensions of the surficial soil source and the groundwater source are identical. For this pathway, the target surficial soil source concentration has to be compared with the representative surficial soil source concentration that can be calculated as discussed below.

The representative surficial soil source concentration should be estimated using the surficial soil data collected within the source zone. Thus, prior to estimating the representative concentration, it is necessary to (i) clearly locate the horizontal dimensions of the source, and (ii) identify the surficial soil data available within the source area. This information should be used to estimate the area-weighted average concentration using the procedure discussed in Section D.4.

D.2.1.2 Representative concentrations for the direct contact pathway. For this pathway, the representative surficial soil concentration has to be based on the receptor's exposure domain i.e., the area over which the receptor may be exposed to the surficial soil. The exact domain of the receptor is very difficult to estimate especially since the domain has to be representative of a period of time equal to the receptor's exposure duration (for example, 9 years for the residential landuse and 4 years for commercial land use). Under current conditions, in the absence of specific information about the receptor's activities, the unpaved portion of the site may be approximately considered as the receptor's domain. For potential future exposures, assuming the pavement is removed and exposure to surficial soil is possible, the entire site may be considered as the receptor's domain.

To estimate the representative concentration for this pathway, it would be necessary to (i) estimate the receptor's domain(s), and (ii) the number of soil samples available within this domain. This information should be used to estimate the area-weighted average concentration using the procedure discussed in Section D. 4. (NOTE: DNR and DOHSS representatives on the group feel strongly that an exception must be made for the circumstance where contamination exists in surficial soils and there are no restrictions on future that would prevent child ingestion. In those cases the representative concentration for the soil ingestion and contact pathway cleanup level must be the maximum in any polygon where a child's play area could be located. The reason is that averaging the representative concentration assumes that individuals move randomly throughout the polygon of potential exposure. However, this is not characteristic of the behavior of children who tend to localize and frequent the same areas. DNR and DOHSS realize that children playing and digging are not likely to uncover three feet of surficial soils. Therefore they would be amenable to redefining the depth of the surface horizon to something less than three feet when considering this pathway.)

D.2.2 Subsurface Soil (greater than 3 feet below ground surface)

The RBCA process includes three routes of exposure associated with the subsurface soil. These include (i) the ingestion of chemicals in groundwater due to leaching of residual concentrations in the subsurface soil, (ii) indoor inhalation of vapor emissions, and (iii) outdoor inhalation of vapor emissions. Thus, three different subsurface soil representative concentrations one for each complete pathway are required. Additional representative concentrations may be required if the receptor's domain for current and future conditions is different.

D.2.2.1 Representative subsurface soil concentration for protection of groundwater. Referring to Figure D-1, the leachate from the subsurface soil source is assumed to travel vertically downwards without any lateral or horizontal spreading. Thus, the representative concentration for this pathway should be based on the subsurface soil concentrations measured within the source area.

As in the case of surficial soil concentration protective of groundwater, discussed in Section D.2.1.1, the representative subsurface soil source concentration would be the volume-weighted average concentration calculated using the data within the soil source area. At LUST sites, the source size is generally small (several tens of feet across) and typically few (1-5) soil samples are available within the soil source. In this case, the arithmetic average of the available data within the subsurface soil source may be used as an approximation for the volume-weighted average concentration.

D.2.2.2 Representative subsurface soil concentration for the protection of indoor inhalation. Subsurface soil concentration protective of indoor inhalation are estimated using the Jury (1983) model. This model assumes that the chemicals volatilize from the sub-surface soil source, and travel vertically upwards without any lateral or transverse spreading, and enter the building through cracks in the floor. Thus, to be consistent with the model, the representative concentration for this pathway should be based on the soil concentrations measured in the soil directly below the enclosed space.

To evaluate the potential future indoor inhalation, i.e., in the event that an enclosed structure is constructed on top of contaminated soil, it is necessary to estimate the size (footprint) of the structure and its location. In the absence of site-specific information subjective judgement has to be made regarding the potential future location and size of the structure. A conservative option would be to locate the structure over the source. The default size of this structure for UST sites is 20 ft by 20 ft. For sites where the footprint of the current and future enclosed space is different, two different representative subsurface soil concentrations (i) for current conditions, and (ii) for future conditions may be necessary.

To estimate the representative subsurface soil concentration for this pathway, it would be necessary to (i) identify the footprint of the structure within which the receptor is located, (ii) identify the footprint of the potential future enclosed structure, and (iii) identify the soil concentration data available within each of these two footprints. The representative concentration would be the area-weighted concentration within the footprint. If sufficient data are not available within the footprint, data adjacent to the footprint, i.e. within 10 ft of the footprint may be used. In no case will data collected more than 10 feet away from the footprint will be used.

If several samples within and adjacent to the footprint are available, more weight should be given to the samples collected within and close to the footprint. Two cases are possible (i) where the building footprint is located entirely within the contaminated area, and (ii) the building footprint is partially located within the contaminated area. In both cases the representative soil concentration should be based on the data collected within and adjacent to the footprint of the building. In the second case since a portion of the building is over the unimpacted area, it would effectively reduce the representative concentration.

Refer to Section D.4 for the estimation of the area-weighted average concentration.

D.2.3 Representative Concentration For Construction Worker

The RBCA process requires the evaluation of two routes of exposure for the construction worker. These include (i) accidental ingestion, dermal contact, and outdoor inhalation of vapors and particulates from soil, and (ii) outdoor inhalation of vapors from groundwater. Thus two representative concentrations (i) for soil and (ii) for groundwater are required. Each of these are discussed below.

D.2.3.1 Representative soil concentration. For the construction worker, no distinction is made between the surficial and subsurface soil because during construction subsurface soil may be exposed to the construction worker. To estimate the representative concentration for the construction worker, it is necessary to identify (i) depth, (ii) areal extent, and (iii) the number of samples within the zone of construction. The potential future depth of construction can be estimated by contacting local construction firms as well as identifying the typical depth of utilities on and adjacent to the site. If the areal extent of the construction area is not known, conservatively it may be estimated as the source area. The representative concentration would be the volume-averaged concentration <u>within this zone of construction.</u> (Note. Similarly to the note in D.2.1.2., DNR and DOHSS believe that at a site where the zone of construction is unknown, and could be anywhere within a given polygon, the representative concentration within that polygon must be maximum. The same reasoning applies, i.e., it is not reasonable to expect that the construction worker will be equally exposed to all points on the site. Rather the worker will more likely be moving through a selected set of points (e.g. a trench), some of which may exceed the maximum calculated health based value.) At UST sites, where the zone of construction is generally small (several tens of feet across), the volume-average concentration may be approximated by the area-weighted average concentration.

D.2.3.1 Representative groundwater concentration. As in the case of estimating representative soil concentrations, it is necessary to estimate the areal extent of the construction zone and the groundwater data available within this zone. The representative concentration would then be estimated as the area-weighted average concentration within this zone. The temporal variation in groundwater concentrations should be evaluated as discussed in Section D.3.2.

D.2.4 Groundwater

The RBCA process requires the evaluation of three routes of exposure associated with shallow groundwater. These are (i) the ingestion of water, and (ii) indoor inhalation of vapor emissions from groundwater. Where multiple aquifers are present, the shallowest aquifer would be considered for the volatilization pathway. Thus, three different groundwater representative concentrations, one for each compete pathway, are required.

D.2.4.1 Representative demonstration well concentration for the protection of groundwater. For the ingestion of groundwater pathway, MCLs or, where MCL's are lacking, federal SDWA health advisories, or other calculated risk based concentrations have to be met at the point of exposure well. Often the point of exposure well is hypothetical and data may not be available from this well. In addition, one or more demonstration wells have to be identified and target demonstration well concentrations (typically higher than the exposure well concentration) have to be calculated at these wells.

For the evaluation of this pathway, the representative concentration should be calculated based on the measured demonstration well concentrations as discussed below:

- For a demonstration well where the plume is stable or shrinking, the representative concentration is the arithmetic average of the most recent one to three year's measurements, provided that the measurements account for seasonal variation.
-

D.2.4.2 Representative groundwater concentration for protection of indoor inhalation. Groundwater concentrations protective of indoor inhalation are estimated using the Johnson and Ettinger (1991) model that assumes no lateral or transverse spreading of the vapors as they migrate upwards from the water table through the capillary fringe, the unsaturated zone, and into the enclosed space. Thus, the representative concentrations for this pathway should be based on the groundwater concentration measured within the footprint of the building. Also refer to Section D.2.2.2 for discussion related to the future footprints and its relationship to the impacted area

For the indoor inhalation of vapor emissions from groundwater, multiple representative concentrations may be required if the plume has migrated below several current or potential future buildings. For example, if a plume has migrated or is likely to migrate below two different buildings (for example on-site and off-site building), an on-site and an off-site representative concentration would have to be estimated. If the plume has migrated below several buildings with similar receptors (residential or commercial) it may be sufficient to evaluate this pathway only for the building below which the concentrations are the highest. If this building is protective of indoor inhalation exposures, it would not be necessary to evaluate other buildings, unless significant differences exist between the two buildings such that the building with the lower concentrations would have offsetting contaminant transport characteristics (e.g., greater percentage of floor cracks or utilities that provide preferential pathways.)

Since the target groundwater concentrations are based on the assumption of no lateral or transverse spreading of the vapors as they diffuse upwards to the building, the representative concentrations should be based on the location(s) of the footprint(s) of the structure(s). After identifying the location of the building footprints and the available groundwater monitoring data within or adjacent to each footprint, the area-weighted average concentration within each footprint has to be estimated, as discussed in Section D.4. Typically groundwater data may not be available for each footprint in which case it would be reasonable to interpolate data between the wells or conservatively use data from the upgradient wells. (Note: In the case where the plume originates under the building, extrapolated data gathered from areas adjacent to the footprint may not be adequate,)

D.3 GENERAL CONSIDERATIONS FOR ESTIMATING REPRESENTATIVE CONCENTRATIONS

The estimation of the representative concentrations requires considerable professional judgements. Prior to performing the computations, identified in Section D.4, the following should be considered.

D.3.1 Surface and Subsurface Soil Concentrations

The following considerations are necessary to evaluate the representative soil concentrations:

- Evaluate whether the spatial resolution of the data is sufficient. Whereas the exact number of samples cannot be specified, data should be available from the areas of known or likely sources and the receptor's domain.
- If the data are "old" (> 4 years old) and the concentrations exceed the Tier 1 RBSLs, or a new spill is suspected, it may be useful to collect recent data. If sufficient new data are collected, they may be used for risk evaluation and the old data may be disregarded. A new release will always require the collection of additional data.
- If there is a "high" density of soil samples or if sampling locations are equally spaced, the arithmetic average may be used instead of the area-weighted average because (i) the area-weighted average and arithmetic average concentrations should be about the same, and (ii) the arithmetic average is much easier to estimate.
- Non-detect soil samples located at the periphery of the domain of interest (e.g. footprint of the building) should not be used.

- Non-detect samples located within the domain of interest may be replaced by half the detection limit.
- If multiple surficial soil samples (highly unlikely) and/or multiple subsurface soil samples are available from the same borehole within the domain of interest; the depth-average or arithmetic average concentration of these samples may be used. If the samples are equally spaced, depth-averaged concentration would be the same as the arithmetic average.

D.3.2 Groundwater Concentrations

The following considerations are necessary to evaluate the representative groundwater concentrations:

- To account for the temporal variation in groundwater concentrations, the concentration in a well may be estimated as:

  (a) For a demonstration well where the plume is stable or shrinking, the representative concentration is the arithmetic average of the most recent one to three year's measurements, provided that the measurements account for seasonal variation. While calculating the arithmetic average, any concentration below detection limits should be replaced by half the detection limit.

  (b) Wells with concentrations consistently below detection limits in the periphery of the domain should not be used.

- For wells that contain or have contained free product in the recent two years, the concentration representative of the well should be the effective solubility of the chemical. Table D-1 lists the effective solubility of selected chemicals in gasoline.(Note, DNR staff believe that in cases where multiple constituents are comingled in the plume, the absolute or pure component solubility may be appropriate)

D.4 ESTIMATING THE AREA-WEIGHTED AVERAGE CONCENTRATION

The area-weighted average concentration can be estimated using the Thiessen Polygon Method (Fetters, 1993 and Linsley, 1975). If the available data are located on a uniform grid, the area-weighted average would be the same as the arithmetic average. At LUST sites, typically the source dimension and the receptor's domain are relatively small (several tens of feet across), and very few (1 to 6) soil samples are available within the soil source. Under such conditions, the arithmetic average concentration may be used as an approximation of the area-weighted average concentration.

Step 1: Identify the Domain

The first and most critical step in this method is to identify the size and location of the domain over which the area-weighted average concentration has to be estimated. The location and size of this domain would vary depending on the pathway being evaluated. Specific guidance on the location of the receptor's domain has been discussed in Section D.2. Area weighted average concentrations can only be estimated if multiple samples have been collected within the domain. If several samples are available just outside the domain, it may be reasonable to extend the size of the domain to include this data. This step is technically justifiable since at most sites the location of the domain is at best approximate.

If the borings or monitoring wells within the footprint are located in a regular grid, the arithmetic average would probably be equal to the area-weighted average. In such cases, the following three steps would not be necessary. As part of this step the various domains for which area-weighted average concentration is desired, should be drawn on a site map and the location of data point (soil borings, monitoring wells) should be clearly located on the map.

Step 2: Discretize the Domain

The domain, identified in Step 1, is discretized into polygonal elements by (i) first connecting the sampling points within each domain identified in Step 1, and (ii) drawing perpendicular bisectors to these lines to form polygons. Estimate the area of each polygon.

Step 3: Estimate Representative Concentration for Each Polygon

The concentration measured at the sampling location within each polygon is considered representative of the area of each polygon. As discussed in Section D.3, if multiple data are available from a location, compute the arithmetic average concentration of each COC measured at that location. The arithmetic concentration is then considered representative of the polygon.

Step 4: Estimate Area-Weighted Average Concentration for the Domain

The area-weighted average concentration for the domain is estimated using:

$$C_{area} = \frac{\sum_{i=1}^{i=n} (A_i * C_{avg,i})}{A_{Total}}$$

where,

C_{area}	=	area-weighted average concentration over the domain [mg/kg]
A_i	=	area of each polygon [m^2]
A_{Total}	=	total area of the polygons i.e. area of the domain [m^2]
$C_{avg,i}$	=	mean of soil or groundwater concentrations measured within the polygonal element i [mg/kg]

An example application of the Thiessen Polygon method is schematically shown in Figure D-2.

D.5 ESTIMATING THE UPPER CONFIDENCE INTERVAL OF THE MEAN

As mentioned above, the area-weighted average concentration over the exposure domain is most representative of the exposure to an individual who randomly moves over the exposure unit. Whereas the receptor may not actually exhibit a truly random pattern, the assumption of equal time spent in different parts of the area is reasonable. As an approximation of the area-weighted average, the true arithmetic average concentration is often used. Unfortunately, the true arithmetic average concentration is not known and cannot be estimated. (The true arithmetic average is a unique value that can be calculated only if the entire population has been sampled i.e., the entire contaminated media analyzed). Since the entire population is almost never sampled, the true mean is never known. Thus at best an estimate of the true mean concentration is possible.

To account for the uncertainty associated with the estimated mean, a confidence interval about the true but unknown mean is often constructed. The interval estimate includes (i) a range and (ii) an associated degree of confidence that the true unknown mean lies within this range. Thus a two-sided 95% confidence interval about the true mean represents a range within which 95% of the estimates of the true mean are likely to exist. This also implies that there is a 5% chance that the true but unknown mean would lie outside these limits. If this interval is symmetrical then there is a 2.5% chance that the true mean exceeds the upper limit and a 2.5% chance that the true mean is less than the lower limit. Note confidence intervals can be estimated for a variety of different confidence levels.

Instead of calculating the two-sided confidence interval, often a one-sided confidence interval is estimated. The upper limit for a one-sided 95% confidence interval of the mean is defined as a value, that when calculated repeatedly for randomly drawn subsets of site data, equals or exceeds the true mean 95% of the time. Alternatively the true mean exceeds the UCL only 5% of the time.

Depending on the underlying distribution of the data and the number of samples collected, the one-sided 95 percentile confidence interval is estimated as follows:

Case 1: The concentration data are normally distributed or more than about 25 sample values are available.

$$\hat{C}_u = \hat{C} + Z_{0.05} \frac{S}{\sqrt{n}} \tag{D-1}$$

Case 2: The concentration data are normally distributed but the number of samples available is less than 25.

$$\overline{C}_u = \overline{C} + \frac{S}{\sqrt{n}} t_{0.05,n-1} \tag{D-2}$$

Case 3: The concentration distribution is log normally distributed i.e. the natural logarithm of the concentration are normally distributed.

$$\overline{C}_u = \exp(\overline{C}_l + 0.5 s_l^{\,2} + s_l H_{0.05} / \sqrt{n-1}) \tag{D-3}$$

Where $\overline{C}_u$ = the upper 95 percentile confidence limit of the mean
$\overline{C}$ = the mean of the concentration
$\overline{C}_l$ = the mean of the natural logarithm of the concentration
S = the standard deviation of the concentration
S_l = the standard deviation of the natural logarithm of the concentration

n = the number of samples used to estimate the mean and standard deviation
$Z_{0.05}$ = the 95th quantile of a normal distribution
$t_{0.05,n-1}$ = the 95th quantile of the statistic t distribution with n-1 degrees of freedom
H = the H statistic obtained from the attached table

The values of Z, t and H static are tabulated in statistics textbooks and are attached to this document for easy reference.

In equations D-1 to D-3, the mean and standard deviation can be calculated as follows;

$$\overline{C} = \frac{C_1 + C_2 ------- + C_n}{n} \tag{D-4}$$

Where C_1-----C_n = the "n" values of concentration
n = the number of measurements
$\overline{C}$ = the arithmetic mean

$$S = \frac{1}{n-1} \sum_{i=1}^{n} (C_i - \overline{C})^2 \tag{D-5}$$

$$C_{li} = \ln C_I \tag{D-6}$$

$$\overline{C_l} = \frac{C_{l1} + C_{l2} ------- + C_{ln}}{n}$$

(D-7)
(D-8)

$$S_l = \frac{1}{n-1} \sum_{i=1}^{n} (C_{li} - \overline{C_l})^2$$

Note the above estimates of the UCL's ensure that (i) concentrations are randomly distributed and (ii) they are uncorrelated.

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APPENDIX I
COMPOSITION OF THE SUBGROUPS

Subgroup Assignments

1) Land Use Considerations

Scott Totten – DNR - CONVENOR
Gale Carlson – DHSS
Carol Eighmey – PSTIF
Eric Klipsch – Municipal/St. Louis
Roger Walker – RCGA (proxy)
Diane Albright – Sierra Club

Only representatives **missing** as per original recommendation is **Financial**

2) Risk Additivity and Target Risks

Gale Carlson –DHSS
Tom Siedhoff – Regulated Community
Contact Bea Covington for Environmental Sector Rep

Only representatives **missing** as per original recommendation is **DNR -**
EPA participation has been recommended by Rich Nussbaum
I need a DNR convenor and that person needs to check with Bill Lowe as to whether EPA wants to be involved.

3) Mathmatical Models

Jim Fels – Implementor
Ed Galbraith – DNR - CONVENOR
David Pate – PSTIF
Keith Piontek – RCGA
Beth Martin – Environmental

Observers:
Diane Maijer (Riverfront Env. observer)
Bruce Stuart (DNR observer)

Group is complete as per original recommendation.

4) Groundwater Classification

Jim Fels – Implementor

Rich Nussbaum – DNR/HWP - CONVENOR
Don Scott – DNR/PDWP
Jim Vandike - GW Association
Steve Sturgess - DNR/GSRAD
Carol Eighmey – PSTIF
Keith Piontek – RCGA
Jim Weston – Well Drillers
Andy Bracker – Municipal/KC
Contact Bea Covington for Environmental Sector Rep.

Group is complete as per original recommendation.

5) Institutional Controls

Tom Tunnicliff – Petroleum
Scott Totten –DNR
Jim Belcher – DNR - CONVENOR
Carol Eighmey – PSTIF
Jim Weston – Well Drillers
Andy Bracker – Municipal/KC
Kevin Perry – REGFORM
Ted Heisel – Environmental (proxy for MO Coalition)

Diane Maijer – (Riverfront Env. Observer)
Rob Morrison – DNR observer
Gary Behrns – DNR - Observer
Bob Geller – DNR - Observer

Only representatives **missing** as per original recommendation is **AGO** (Duggan)

6) Nuisance Controls

Jim Fels – Implementor
Tom Tunnicliff – Petroleum
Gale Carlson – DHSS
David Pate – PSTIF
John Madras – DNR - CONVENOR
Jim Weston – Well Drillers
Contact Bea Covington for Environmental Sector Rep

This group is complete as per original recommendation.

7) Ecological Risk

Scott Totten – DNR
John Madras – DNR - CONVENOR
Andy Bracker – Municipal/KC
Kevin Perry – REGFORM
Bea Covington - Environmental

Tim Chibnall – DNR observer
Dave Mosby – DNR observer

EPA participation has been suggested by Rich Nussbaum – Convenor please get in touch with Bill Lowe to ask whether they are interested.

8) Representative Concentrations

Rich Nussbaum – DNR
Ed Galbraith - DNR - CONVENOR
Tom Tunnicliff – Petroleum
Gale Carlson – DHSS
David Pate – PSTIF
Tom Siedhoff – Regulated Community
Contact Bea Covington for Environmental Sector Rep

This group is complete as per recommendation.